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The
New Human Interest Library

Volume II

Painted for The New Human Interest Library

Blessings on Science! When the earth seem'd old,
When faith grew doting, and our Reason cold,
'Twas she discovered that the world was young,
And taught a language to its lisping tongue.

—CHARLES MACKAY

The

New Human Interest Library

VOLUME II

Stories of Science

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Book *of* Earth and Sky

The Story of the Earth
Earthquakes and Volcanoes
The Weather
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The Solar Spectrum
In the Depths of Space
Measurements of Time

THE CHARM OF LAKE, MOUNTAIN AND GLACIER
Lake Louise and the Victoria Glacier in the Canadian Rockies.

THE STORY OF THE EARTH

TO US the earth is very great, and of measureless importance. In actual fact, it is one of the smallest members of the group of planets which rush along, turning over and over, around a central sun, likewise small of its kind. These constitute our solar system. It takes us just a year to go around our sun; just a day to turn over, and just a month for our little moon to make her journey around us. With all this going around and around among ourselves, our whole solar system is rushing at prodigious speed toward somewhere, and an enormous, perhaps unlimited, number of other solar systems are likewise rushing onward.

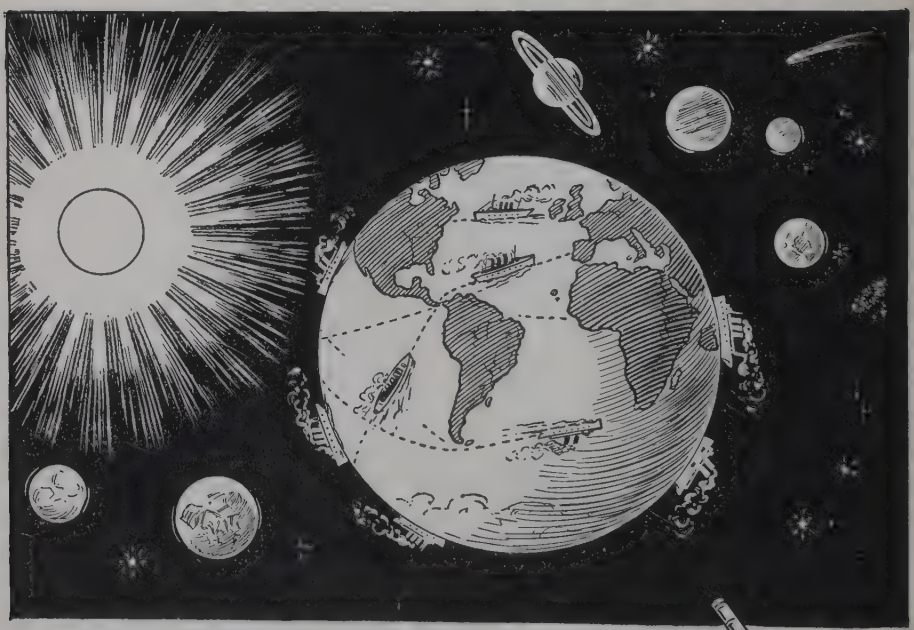
We are all enveloped in the infinite order which seems to provide that none of these shall ever come into collision. The parts of the universe are always moving, never at rest, and never in disorder. The operations of everything we know are summed up as orderly change. The problem of the origin of the earth, how it came to be and what is to be its final fate, if indeed it comes to any end, are still beyond our knowledge. Man, even aided by telescope, microscope, spectroscope and all the other instruments of precision, can see but a short distance back into the dark or forward into the mist-covered future. He can discern and describe human experiences, can test them and set them in order; and what he finds out is truth. But his truth, however extensive and valuable, is but a little clearing in the great forest of the unknown—a floating island in the Unfathomed Sea of the Universe.

We know that life on the earth is conditioned on heat, air and water. We are fairly certain that once, long ago, the surface of the earth was too hot for animals or plants to exist upon it. We know that today living forms of a million kinds have been found, named and recorded.

Whether our solar system has developed from revolving cooling matter or star dust flung off from a cooling sun, as most scientists seem to think; whether, traveling through space, it has been gathered by picking up bodies on the way, as we pick up meteors or

THE EARTH AS THE ANCIENTS THOUGHT IT WAS

Men used to think the earth was flat with fires always burning below. These fires were said to be the source of volcanoes. Our picture shows what these men thought was the whole world.



THE EARTH AS WE KNOW IT TO BE TODAY

Our artist has shown the earth as the great round ball we know it to be. Ships can sail round the globe and we can look at other worlds through the telescope.

shooting stars; or whether it grew up in some more favorable way which we have not guessed, is still unknown.

Whether the earth is cooling off and the whole system is to run down in a few million years, like an unwound clock, or whether it is just beginning to warm up for fresh adventures, we do not know. And to pretend to know only shows our ignorance.

But the earth is ours; we were born on it, dwell on it, and, so far as we can own anything, we own the earth. When all is said, this is a very marvelous world of ours. If we live wisely, life upon the earth is very happy. It is well, therefore, for us to study and become acquainted with our own inheritance. To tell something of what the earth is like and what it contains, is the purpose of the descriptions that follow.*

THE ROUND BALL ON WHICH WE LIVE

The earth is round like a ball. When we sail away from a shore we can easily see that its surface is not flat but curved. The huge, low-lying rocks disappear from view first and the slender top of the lighthouse last.

A GENERAL VIEW OF THE EARTH

The great land masses of the earth are called continents. These are Europe, Asia, Africa, North America, South America, Antarctica and Australia. The latter two are sometimes called island-continents.

The larger part of the earth is covered by salt water. The great bodies of water that spread over the surface of much of the earth are called oceans. They are named Pacific, Atlantic, Indian, Arctic and Antarctic.

OCEAN CURRENTS AND WHAT MAKES THEM

An ocean current is a stream-like movement following a definite path in the sea. The cause of this movement is partly found in the revolution of the earth, a movement most rapid at the equator because the earth at its middle goes farther than it does near the poles. It has farther to go every time the earth turns around. The currents going north from the equator naturally bend toward the east, going faster than the land itself, as the earth moves from west to east. The cold current coming from the north to restore the equilibrium or balance of the water tends to slip westward, and

*The writer is indebted to his former student, Caspar W. Hodgson, of the World Book Company of Yonkers, N. Y., for permission to use certain ideas and a few paragraphs published in Jordan and Cather's *High Lights of Geography, I. North America, II. Europe.*

causes the climate on the shores it touches to become colder than they would normally be. There are also various other types of ocean currents, especially around the equator, some of which find their explanations in the positions of islands. There is, for example, a considerable movement of water in the South Seas from the East Indies toward, but not to, the American continent. After a time it turns backward on itself, turning to the northward as it meets the now cold Japan Current. With it, it moves westward past Hawaii. All these currents spread more widely over the ocean as they move forward, and their rate of motion is steadily lessened.

THE FRIENDLY GULF STREAM

The Gulf Stream is a large, sweeping current of water from the West Indies, which grows wider, cooler and shallower as it moves northward, through the Florida Straits, along the coast of Florida and the Carolinas, finally reaching the shores of Scotland and Norway, making these regions much warmer and wetter than similar coasts elsewhere in the same latitudes. A similar "gulf stream" called the Kuro Shiwo, or "black current", flows from the Philippines northward, bathing the eastern shores of Japan, making them warm and wet. It continues to the Aleutian Islands of Alaska. There turning southward, its waters chilled, it extends along the coast of California to Point Conception, whence it turns westward and is lost in the sea.

THE GIANT THAT TUGS AT THE WATERS OF THE EARTH

A tide is a movement or motion of the surface of the sea due to the influence of the sun and moon. Twice each day, or every twelve hours, the surface of the ocean rises and falls. The sea rolls landward for about six hours, then back from the shore for the same length of time, as if some giant were pulling it back and forth. There *is* a giant tugging at its waters, which being fluid move with great readiness, keeping eternally in motion, and that giant is the moon. Being nearer the moon than the body of the earth is, the water responds more quickly to its attraction. The sun, too, has its effect upon the tides. When the sun and the moon pull together, we have the highest, or spring tides. When they are far apart, the lowest, or neap tides, appear.

The tide is changed in all sorts of ways by the form of the coast. Out in the open sea the tides are very low. In enclosed waters, like the Mediterranean, they are also very low, because they are set off from the great wash of the ocean.

The highest tides in all the world are in the Bay of Fundy, between New Brunswick and Nova Scotia, in Canada, where they rise to a height of fifty feet or more. The reason for this is found in the form of the bay, wide at the mouth and growing evenly narrower, up to the very head. Moreover, the Bay of Fundy is a part of the Atlantic, instead of being attached to an inland sea like the Mediterranean. It is therefore not protected from the great wash of the ocean. Into such bays the tide rushes, sometimes with a loud roar.

When the tide goes out, the sediment it has carried is left in the form of mud deposits at the head of the bay. In these deposits tracks are made by birds, dogs, crabs, and occasionally by fish left stranded. When the water is out the mud dries and hardens in the sun. When the tide comes in again, the sediment fills up the tracks left by various adventuring creatures. Thus the process goes on from year to year. If ever the

THE SPERM WHALE—THE TIGER OF THE DEEP

Possessed of amazing strength this monster of the seas sometimes turns upon the whalers. When this occurs at night, and it soars into the air made luminous by phosphorescence, it is like the extension of some gigantic flame cone from the deep.

A PHOTOGRAPH OF THE MOON

This dead world, lit up by the light of the sun, is the giant that tugs at the waters of the earth, causing tides. The sun, too, has its effect upon the tides.

crust of the earth shifts and the bed of the Bay of Fundy becomes dry land, and these mud and clay deposits harden permanently into stone, the imprints left by the feet of birds and dogs will be found there. A track once made in the mud may not wholly disappear, if the mud dries afterward and fresh deposits fill up the old marks.

CORAL POLYPS—ARCHITECTS OF ISLANDS OF THE SEA

A reef is a line of rock rising near the surface of the sea or sometimes somewhat above it. While the word reef is not rigidly defined, the name is commonly used for either of two different sorts of formations. A coral reef is a mass of limestone attached to or near a shore, and is made up of the lime structures produced by coral animals (polyps) abounding in tropical seas. Other minute animal forms, known as *Foraminifera*, also take part in reef making. These creatures secrete carbonate of lime. Coral polyps are of varying sizes, occasionally single, having the form of a mushroom, more often small and gathered together in

one mass. These masses may be very large and spherical, as big as a great basket, the different creatures scattered over it making it look like the surface of the brain (hence the name, "brain corals"), or they may be smaller and branching, the branches suggesting twigs.

A coral reef which hugs the shore is called a fringing reef. One separated from the shore by a channel, is called a barrier reef. A fringing reef lines the shore where the water outside grows deep rapidly. A barrier reef is often a mile or two wide, and, at low tide, more or less bare, covered with

MARY ISLAND

Sketch made by Dr. Jordan of a little coral island, or atoll, on the equator, northwest of Samoa. To please his young son, Dr. Jordan put in a band of tourists, though people probably never landed on the atoll.

pools of water in which gayly colored little fishes and multitudes of eels find their homes.

The reefs are not built by the coral animals, but are composed of dead structures, pounded on by great waves and piled up on the surface like scrap iron. As carbonate of lime is somewhat soluble in water, the masses become, in time, more or less solidified, sticking together much as dampened sticks of candy will. Corals will not live in deep water, nor where fresh water flows in. Where a river flows into a coral bay it cuts a channel right through the corals, thus giving entrance to an inner harbor behind the barrier reef.

Besides the ordinary corals, the white structures of which are made of carbonate of lime, there are numerous other species, usually red in color, with skeletons of a horny substance. Colonies of these form branches like a tree, the individual animals being very small.

THE MAGIC CIRCLE IN THE SEA

An atoll is a small coral island, ring-like in form, with an opening or break on one side, by which the sea enters. In its origin it is usually regarded as a fringing reef which had been formed about a sunken or sinking mountain. This was the view of Darwin. Some recent students hold the same opinion; others hold that they are built up on submarine platforms in water not too deep. Atolls are found in the western part of the South Seas, and are supposed to mark the summits of a sunken continent. The writer once sketched Mary Island, an atoll on the equator to the west of Samoa.

I know a magic circle in the sea,
Etched on the blue with pale gray coral sand;
A mountain sank there once amid the spray,
Its swirling eddies stiffened into land,
With lazy surges flapping on the strand.

In various regions, long lines of rock under the water at high tide are known locally as reefs. These may be of volcanic origin, submarine dikes of lava, or they may be of granite or other hard rocks which the wash of the sea has failed to carry away. However they have been formed, they are often very dangerous to ships.

PICTURESQUE LAKE FAIRFIELD, NORTH CAROLINA
An exquisite bit of lake and mountain scenery in the "Land of the Sky."

Ways in which lakes are made

A lake is a body of water within the land. Lakes which have an outlet to the sea are of fresh water, but where the evaporation is so great that they no longer overflow their rims as in the case of the Great Salt Lake, the Dead Sea, and many others, the water becomes more or less salty or alkaline.

In general there are three types of lakes. The great majority of small lakes are depressions which have been excavated by glaciers, often with a dam, made of materials deposited by a glacier, at the end, through which a stream breaks its way. Other lakes are produced by the closing up of sandy bays along the seashore. These are usually known as sounds, until the salt water is entirely shut off. Of this nature is Lake Pontchartrain, near New Orleans, and Lake Sabine, between Louisiana and Texas. A still smaller class of lakes is produced by tectonic (referring to movements of the earth's crust) disturbances, causing the sinking of larger or smaller tracts of land which fill up with water.

The largest lake in the world is Lake Superior. This and other great lakes fill beds originally due to tilting or warping of the earth's crust on a huge scale. The so-called Finger Lakes of western New York—Cayuga, Seneca and several others—are illustrations of river valleys scoured out by ice and then blocked at the end by moraines. Among the lakes produced by sinking or tilting of the crust are Lake Elsinore, in southern California and Lake Chapala, in Mexico. Reelfoot Lake in western Tennessee is the result of a violent earthquake on unconsolidated deposits.

Another type is Lake Tahoe, in California. Here a river bed was crossed by a great lava dike. Crater Lake, in southern Oregon, is a volcanic crater filled with water.

Lakes that have no outlets

A salt lake is one which has at present no outlet, the water no longer flowing into the sea. In a salt lake the inflow from streams is reduced by evaporation, and the level of the lake, with some fluctuation by seasons, remains at a point where the evaporation each year balances all that the streams bring in. Common salt (chloride of sodium), and other chlorides, iodides and bromides, are dissolved

from rocks by flowing water along the courses, especially of the smaller streams. As these salts do not evaporate, they become concentrated in a lake without overflow, and the degree of saltiness depends on the age of the lake. In some cases the lake is more or less saturated with salt in a few hundred years, and in some it is still imperfectly salty. In the Caspian Sea, some fishes are found coming down from the Volga River which are stunted examples of the same species in the Black Sea and the Mediterranean. In the Dead Sea and in the Great Salt Lake there are no fishes whatever, because fish cannot breathe in the extremely salty water. The only life in Great Salt Lake consists of brine shrimps and the larvae of a certain small fly.

Glaciers and ice sheets

A glacier is a slow-moving mass of ice produced by the compacting of snow in large masses. Glaciers arise at the summits of snow-clad mountains. Those of Switzerland are best known. A continental glacier or ice sheet covers vast stretches of land, and expands largely under its own weight and by the continued accumulation of snow. A huge continental ice sheet once, many thousands of years ago, covered a large part of North America, extending as far south as Long Island, Indianapolis and St. Louis; but gradually it melted away, leaving behind "drift soil" and boulders, called "erratics," brought from the north. A continental ice sheet still exists in Greenland. The Alpine glaciers bring down rocks and soil which are piled up at their fronts and along their sides forming ridges, and often a horseshoe-shaped mass or dam at the end, called a moraine. A glacier scours and usually deepens its bed, forming lakes by excavation or by moraine dams—usually by both. Most small lakes are due to glacial action, as are also the narrow deep bays with rocky walls, known by the Norwegian name of "fiords."

A few points as to glaciers may be noted. When the ground over which the glacier moves is uneven, the ice mass breaks and develops great cracks called crevasses. These sometimes extend to the very bottom of the ice. Most glaciers carry on their sides a long line of rocks which the frost has broken off from cliffs above. If a crevasse opens, some of these rocks then fall in and are shoved along, thus grinding against one another, as well as against the hard floor underneath. This grinding wears off all angles, leaving the surface of the grinding boulders and that of the floor polished and marked by parallel scratches, known as striae. If the rocks are rolled over and over, they become both rounded and smooth. Those that ride along on the surface of the glacier without falling into a crevasse, remain angular and rough, because there has been no friction to polish them.

When there is a sudden and steep drop in the surface over which the glacier moves, a series of crevasses will open wide, and the ice walls will break and pile up in irregular masses, or pinnacles.

It is interesting to note that each glacier has its own individuality, no two being quite alike. Some, the Mer de Glace Glacier, on the flank of Mont Blanc, for instance, may in some places be crossed without fear. Some crevasses are always dangerous for mountain climbers; others are at times unsafe, particularly when covered by new-fallen snow.

The largest glacier in North America comes down from Mount St. Elias, Alaska. It is known as the

Wide World Photos

A CHILD OF THE GREAT GREENLAND ICE CAP

An iceberg—ocean-child of the glacier—broken away from the great arctic fields which cover an area of almost 500,000 square miles.

Malaspina Glacier, and is forty miles wide above the place where it breaks into the sea. The next largest is the Muir Glacier, which comes down into Glacier Bay from peaks about Mount Fairweather, Alaska. Where it reaches the bay, the wall of blue ice is more than a mile wide and five hundred feet high. The largest glacier in the Alps is the great Aletsch Glacier, which flows down toward the Rhone River.

THE MORAINES WHICH THE GLACIERS MAKE

A moraine is a deposit of rock waste laid down by glaciers. It is made either of material that has been broken or scraped off from the bottom of the glacier channel, or that which has reached the bottom by falling into a crack in the ice, or which has been thrown down by frost on the glacier surface. A lateral moraine is a ridge of such material along the side of a glacier. A medial moraine is a long line of rocks and stones on the middle part of the glacier. It is formed where two glaciers unite, two lateral moraines joining to form a medial one. A terminal moraine is a pile of rock waste dropped at the lower end of the glacier. A terminal moraine is more or less crescent-shaped in form, the horns of the crescent being continued in the lateral moraines. The existence of moraines in great numbers far below the ends of present glaciers shows that the glaciers of the Ice Age were of relatively great extent. The glacier of the Rhone, in Europe, for example, is known by its erratics and moraines to have once extended as far as Lyons in France.

THE ICEBERG—OCEAN-CHILD OF THE GLACIER

An iceberg is a mass of ice broken off from a glacier which advances into the sea. In the far north, in Norway, Greenland and Alaska, a number of glaciers reach the ocean. Before melting, being lighter than water, the ends

break off and move seaward as icebergs. The largest of these come from the west shore of Greenland. They travel southward in the Polar Current to Newfoundland, melting rapidly as they enter the Gulf Stream. Around the island of Newfoundland the icebergs reach farthest south and are a menace to navigation.

A great iceberg is a most impressive sight; the greater part of the huge mass is below the water, but even the part above, with its shafts and pillars of ice, is very striking. The glaciers which reach the sea form, according to Bret Harte, "Nature's dock from which she slips to the sea her ice ships."

Soil and how it is made

Soil is the loose surface covering of the earth as distinguished from the more solid base of rock over which it lies. There are in general three kinds of soils—soil in place, alluvium and drift. Soil in place is produced mainly by the chemical decomposition of rock, which is promoted by the presence of water carrying acids, by the presence of bacteria, by the action of plant roots, and in some places by the action of earthworms. Some soils are formed by the mechanical disintegration of rock by the action of such agencies as frost, solar heat and temperature changes. Alluvial soil is brought down by rivers, forming flood plains and deltas when on a large scale. The third type of soil is known as drift. It is brought down by local glaciers and from the north by continental glaciers. Alluvial soil is, in general, the richest. Soil in place is often barren. Drift soil is considerably more uniform and more fertile than soils beyond the limits of glacial action. The southern line of continental drift soil in the United States runs near Newark, Pittsburgh, Cincinnati, Indianapolis, St. Louis and Kansas City, and thence northwestward to the front of the Rocky Mountains. In Europe the drift is more generally local, as is natural from the situation of the mountain chains, which leave little room for a uniform ice sheet.

Loess is a German name applying to masses of yellowish or reddish loam sometimes, especially in China, of great depth and extent, where the wind helped its formation. The name was first applied to loamy deposits along the Rhine in Germany. In many cases the formation of loess is apparently due to the wash of water on glacial material.

Behold the mountains

A mountain is an elevation of rocky land, larger than a hill and usually more broken. Most mountains are produced by foldings of the crust of the earth, their outlines being left rugged by the erosion which follows. Many of them are composed of granite or other rocks of igneous (fire-formed) origin. Some mountains are made of lava, and have within their extent a series of volcanoes, either active or extinct or erupting at intervals. The lines of volcanoes commonly follow earthquake rifts, which become "healed" by pressure. Most mountains are formed as chains, each one originally a continuous fold, usually one of a series of folds. The highest mountain on earth is Mount Everest (29,003 feet), in the Himalayas of India. The highest in North America is Mount McKinley (20,300 feet), of the St. Elias group in Alaska. The highest in the United States is Mount Whitney (14,501 feet), of the Sierra Nevadas of California. The highest in Europe is Mount Elbruz (18,465 feet), in the Caucasus, between the Black Sea and the Caspian Sea. In the Alps, the highest is

Mont Blanc (15,781 feet), though several others are but little lower. Of these, the Matterhorn (14,780 feet), is the most outstanding for "no other mountain in the world makes such use of its height as the Matterhorn."

Experiences with avalanches

An avalanche is a mass of snow falling from the side of a mountain. It may be new snow, not yet united into a mass, or it may be old snow more or less compacted into ice. It may bring with it fragments of rock, large or small, sometimes very huge. Byron describes an avalanche as "a thunderbolt of snow."

Avalanches at times do great mischief. When they dam up rivers they cause destructive floods. About a hundred years ago, in the Valley of Bagnes above Lake Geneva, in Switzerland, there was large loss of life and property when a fall of ice and snow blocked the river and turned the portion of the stream above the dam into a lake. Avalanches of stones only occur frequently on the great steep slopes where fragments of rock, loosened by frost, are thrown off daily. Each stone as it falls may loosen hundreds of others. This I have seen frequently in the Alps, especially on the northeastern slope of the Matterhorn in Switzerland. In my record of "The Ascent of the Matterhorn"*, I gave this account of a rock avalanche:

"As we descended, the treacherous character of the Swiss face became increasingly evident and alarming. As a matter of fact the whole outer surface of the mountain is loose, scarcely a rock anywhere being firmly attached. Far into all the joints of the strata, water from melting snow finds its way, to freeze at night and thereby widen

MOUNT McKINLEY, ALASKA

The highest peak in North America. It is situated in south central Alaska. It has many glaciers.

*From David Starr Jordan's *Days of a Man, Vol. I.*

the joints so that the outer blocks, large and small, are daily pushed towards the edge. Thus nothing is stable, and each year the Matterhorn offers everywhere a new face to the weather. But the dip of the strata being strongly to the south, on the Swiss (northeastern) side the loosened blocks remain poised on uplifted edges until thrown off, when the fall of a single one will start a regular shower below. In the afternoon the danger is most acute, the ice cement having thawed and released the debris. On the Italian front, on the contrary, a rock drops as soon as loosened, and so without starting a volley.

"Working along, we soon heard a terrible uproar, and three or four rods away saw an immense avalanche of rocks—a dozen of them as large as a wagon, with hundreds of little ones yelping in the rear. 'C'est une montagne terrible!' exclaimed Jean Baptiste, our chief guide."

Glaciers travel so slowly that there is no danger from them to people living in the country below. But sometimes in the mountains there are avalanches, masses of snow and loosened rock that plunge down very rapidly and destroy whatever happens to be in their way. Occasionally villages and many lives have been wiped out in this way.

During the summer of 1883 I was in the Bernese Oberland between the Wellhorn and the Wetterhorn, just east of the Jungfrau. One day, as several of us were passing through the pretty meadow called Geschwandenmaad, covered with gentians and other Alpine flowers, we noticed a great mass of snow and ice sliding along on the level top of a very high perpendicular cliff, barely a third of a mile away. Below, on a low ridge, beyond a narrow valley, shepherds were blowing their horns with vigor, at each blast jarring off a considerable amount of the snow at the edge of the precipice. Suddenly the whole white mass, covering perhaps a half acre, and several hundred feet deep, slid over the cliff, falling a thousand feet with a great roar and filling up a considerable part of the little valley at its foot. For a distance of many rods away, the heads of flowers were cut off by the flying scraps of ice and piled up in windrows.

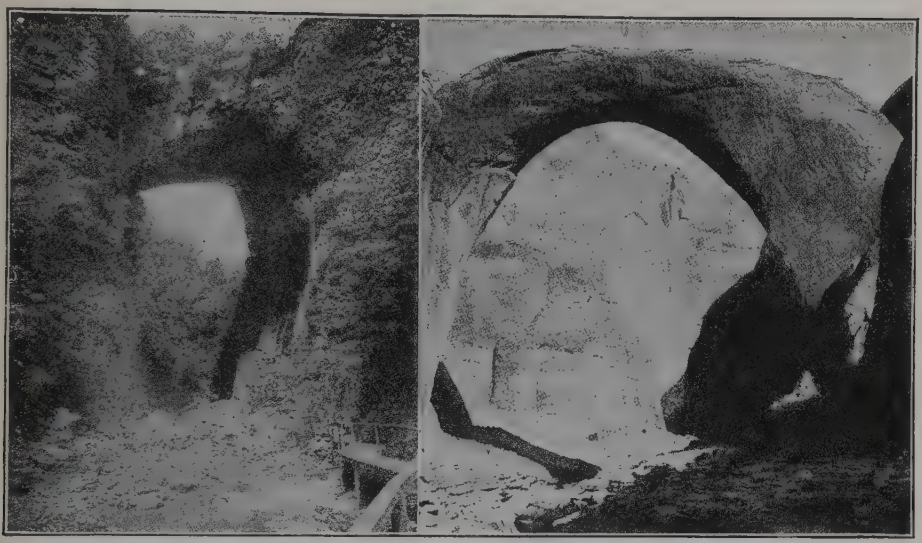
In the high Alps, in summer time, one may often see small avalanches. The mountaineer is especially careful to avoid going into places where these masses are likely to fall, because to do so means to risk his life. It happened that the avalanche that I watched did no damage, except to the flowers in the meadow, and the sight was very impressive. Usually, however, these plunging masses are so terrible that people hold them in constant dread. As a very slight disturbance in the air may start an avalanche, the guides sometimes forbid a group of people even to speak as they pass a treacherous stretch of snow.

"Stand here and look and softly hold your breath,
Lest the great avalanche come crashing down."

—J. M. Aldrich.

When the Earth Slips—Landslides

A landslide is the slipping down of a large mass of earth or rock on a mountain or any steep slope. In 1890, after a great landslide, I visited the town of Elm, in the canton of Glarus in eastern Switzerland. The descending mass had covered the whole east side of the town, burying houses and people deep in broken rock and mud. For a time it blocked the stream which flows through Elm, causing it immediately to rise, and threatening to submerge those who had not been caught by the slide. By the time I arrived, the



NATURAL BRIDGE, VIRGINIA
This famous arch is 215 feet high and has a span of 90 feet. It is near Lexington, Virginia.

NONNEZOSHI BRIDGE, UTAH
Another striking example of erosion. This arch is 308 feet high and 273 feet long.

water had been drained off; the dead—115 in all—had been buried, and some work had been done toward excavating the rest of the village.

Another remarkable Swiss landslide took place many years ago in the Maloja Valley, in the canton of Ticino, near the Italian border, burying many houses. Plants and shrubs are now growing over a mass of rock which covered all of one part of the town, except the spire of a church.

THE GRAND CANYON OF THE COLORADO AND HOW IT WAS MADE

A cañon (pronounced kan'-yun, and usually in the United States spelled "canyon"), is a deep gorge with steep walls, the result of centuries of stream cutting. The word "gorge" is most common in regions where there are not large canyons. The word "cañon" is Spanish and is used only in the western part of the United States and in Spanish-speaking countries. The greatest of the many prodigious cañons in the United States is the Grand Canyon of the Colorado, in Arizona. It is the most typical as well as the most gigantic example in the whole world of a gorge cut out by water.

Countless ages ago, after the region that is now the southwestern part of the United States had risen from the sea, a great, uneven plateau was formed in northwestern Arizona. Over this plateau flowed rivers which, as time went on, cut down their channels and widened their valleys. The different strata, or layers, of rock remained nearly level as they were when deposited, having suffered no great alteration except, here and there by dislocations along fault fractures and by bending, masses of lava have been thrust out. Some of the lower rocks were softer than those above, and hence, there were left series of flat-topped hills called "buttes," or, when large, called "mesas," or table-lands, with sheer walls such as one sees in mountainous parts of the West. As century after century passed, the most powerful of these rivers worked down to a lower layer of very hard rock, in

THE SPELL OF THE GRAND CANYON OF ARIZONA

The Grand Canyon is not a solitude. It is a living, moving, pulsating being, ever changing in form and color, pinnacles and towers springing into being out of unseen depths. From dark shades of brown and black, scarlet flames suddenly flash out and then die away into stretches of orange and purple.

which it, at first, could cut only a rather narrow channel. But slowly, unceasingly, the stream carved its way down, and as it went deeper and deeper it formed a gorge with abrupt walls. For ages the river continued to saw through many different rock layers, until a mile of vertical depth was washed away. Thus was formed the most marvelous gorge the world knows, a place of stupendous beauty and weird magnificence, unlike anything else upon our globe.

Inside this great canyon are ridges and peaks high enough to be mountains themselves. The highest mountain in New England, outside of a few of the White Mountains, is not high enough to reach from the bottom to the top of the canyon.

The first exploration of the Grand Canyon was made by Major J. W. Powell, who, with nine men, set out in four boats in 1869 to follow the course downward of the Green River and the Colorado. They went through a long series of canyons, descending many rapids. In the greatest gorge, the Grand Canyon, they did not know but that at any bend their boat might dash over a vertical fall; but they found that they could get around most of the rapids in safety. Some rapids they were obliged to descend in their boats at great danger to their lives.

One day they came to an extremely muddy side stream, cutting its way through a desolate region of bare rocks on the northwest bank. This they named the Dirty Devil River (since renamed Fremont River). Some miles farther down was a stream that was crystal clear; they named this Bright Angel Creek.

Two years later, Major Powell with ten men again explored this wonderful waterway, this time for the United States Government. They devoted two years to securing data for maps and other information.

When you go to see the Grand Canyon you will find a great hotel with its bungalows above the river on the south rim, opposite the beautiful Bright Angel Creek. You can go down into the canyon over a narrow winding trail and the burro you ride will walk so close to the outer edge that you may be frightened. But the burro knows what he is doing, for if he keeps close to the outside, especially if he has a burden on his back, he is less likely to be shoved off into the abyss.

WHEN THE EARTH IS GNAWED AWAY—EROSION

Erosion is the wash of streams. Every part of the world shows erosion in some degree. The word means "gnawing away," a phrase which tells what rivers and tides can do. Erosion, on a broad scale, is called denudation or "making bare."

THE COKE OVENS

The "Coke Ovens," eight miles west of Grand Junction, Colorado, present a striking example of the work of erosion.

VICTORIA FALLS, RHODESIA, AFRICA

A magnificent cataract on the middle Zambesi River. The river plunges to a depth of 400 feet. The native name for the falls is Mosi-wa-Tunya, or "Thundering Smoke."

FALLING WATER—CATARACTS AND CASCADES

Among the grandest displays in nature are the countless forms of waterfalls. When these are large they are called cataracts, and when they are smaller, especially if they are in series, they are known as cascades. Whatever their size, waterfalls are the results of the gnawing tooth of erosion at work on rocks of varying degrees of hardness. When this situation occurs in the path of a stream, the result is a waterfall. If the rocks at the surface are harder than those below, the fall becomes vertical. If the uppermost rocks are not resistant, the fall may have various forms—a series of cascades, or perhaps a line of rapids.

Niagara Falls is a cataract that has been cutting its way back ever since the ice period. On January 18, 1931, the contour was altered by a rock slide of 75,000 tons. The moving back of the cataract is due to the erosion by water of the softer rock underneath. The top rock is hard limestone, but when the under structure is removed, the top rock drops off in huge pieces and the cataract moves back. This process, continued through centuries, has set back Niagara Falls six miles and left, in the path of retreat, the famous gorge between the fall and the great whirlpool, at which point the river suddenly changes its direction, its former channel, now called St. David's Glen, having been blocked up by ice and moraine deposits.

THE U-SHAPED CIRQUE

A cirque is in general an amphitheater-like valley head or mountain recess inclosed by U-shaped cliffs or steep slopes. Such forms may be produced by different processes, mainly, however, by stream and glacial erosion. Most common by far are the glacial cirques—that is, cirques that have been made from stream-cut valley heads, or gulches, by the cutting action of glaciers. There are

NIAGARA FALLS

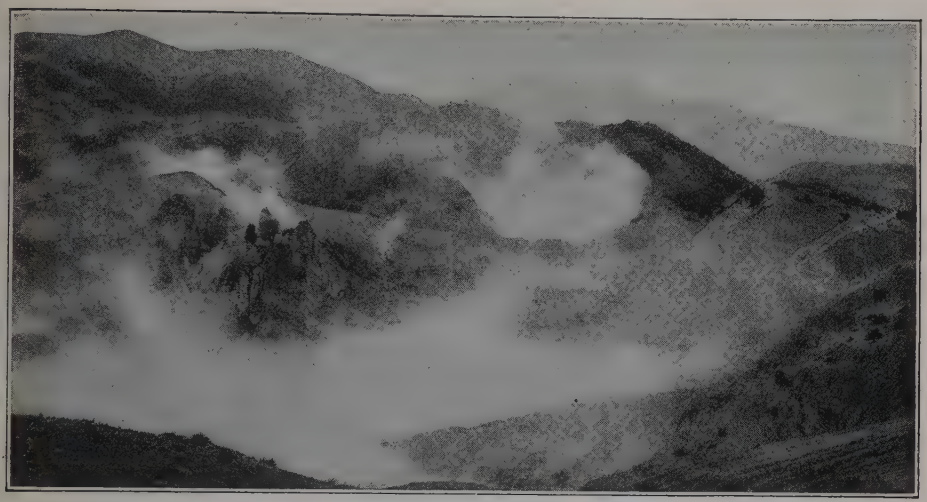
Showing the American Falls in the left foreground and the Horseshoe or Canadian Falls in the right background. Between the two falls is Goat Island.

GIANT GEYSER, YELLOWSTONE NATIONAL PARK

One of the most remarkable geysers in America is the Giant, which throws a column of scalding water to a height of about 200 feet. There are at least seventy geysers in Yellowstone National Park.

THE GARDEN WALL, GLACIER NATIONAL PARK, MONTANA

This beautiful cirque was hollowed out by a glacier in the Ice Age. A remnant of the glacier remains and furnishes little icebergs for Iceberg Lake which lies at the base of this cirque.



WAIMANGU GEYSER, NEW ZEALAND
The world's largest geyser, Rotorua, North Island, New Zealand.

thousands of these in the Alps, the Pyrenees, the Rocky Mountains, the Sierra Nevadas, the Himalayas; indeed, in all lofty mountains that bore glaciers during the Ice Age. Glacial cirques are characteristically shaped like half-bowls and possess broad, fairly level, or stepwise descending floors, commonly holding shallow rock-rimmed lakelets. Many of them open at a considerable height above the main valleys.

In this country especially fine examples of cirques that still contain glaciers and are still being enlarged by them are to be seen on Mount Rainier, Washington. The cirque of the Carbon Glacier, on the north side of that peak, is the largest and scenically the most impressive. Iceberg Lake, in Glacier National Park, Montana, lies in the bosom of a small but very beautiful cirque. The icebergs for which it is named break off from the front of a little glacier, a remnant of the powerful glacier which occupied the hollow during the Ice Age. The celebrated cirque of Gavarnie, in the Pyrenees, is now entirely empty, but several ice fields still linger on the peaks and crests that surround it.

EARTH FAULTS AND EARTH DISTURBANCES

A fault is a long rift, or crack in the rocky crust of the earth. It comes in view usually in connection with earthquakes. In regions of disturbance, the crust has been broken ages ago into huge rock blocks, which shift at times, by yielding to strain on them. The walls of a fault or rift will grind upon one another producing disturbances called "earthquakes." Faults are of various lengths from a few miles to a thousand. A fault may extend to great depths. Some of them probably go down as far as the solid crust goes, perhaps for forty miles. A fault may extend for a long distance along the surface, perhaps for thousands of miles, being covered by soil, except when disturbed by earthquakes. (See "Earthquakes and Volcanoes" Page 31)

NATURES GREATEST FOUNTAINS—GEYSERS

A geyser is a spouting spring of hot water. It is a result of the flow of underground waters over buried lava which is still hot. The usual condition

may be thus described: Surface water trickles down through fissures in the rock, and, in contact with hot lava, becomes heated, and the superheated steam blows out the water which lies above. In time, the deposition of silicates along the walls of the break converts it into a tube lined by a deposit of the nature and appearance of porcelain. The contents of this tube are shot into the air, at varying intervals and with varying intensity, according to the size, depth and nature of the tube and its surroundings. A geyser district is one in which great lava masses are gradually cooling. As a result, all geysers are slowly dying. The chief geyser regions are the Yellowstone Park, Iceland, and Rotorua, a famous resort in the north island of New Zealand.

The most noted of the hundreds of geysers is "Old Faithful" in Yellowstone Park. This spouting spring gave for many years a most beautiful eruption very regularly every hour. In 1932 a considerable variation was observed, ranging from intervals of thirty-eight to eighty-one minutes. In the same region is "The Minute Man," a geyser which ejects its little column of water for two or three feet, once every few minutes.

Springs—cold and hot

A spring, or fountain of water, occurs wherever ground water comes to the surface. The outflow of springs gives rise to brooks, rivulets or rivers. Most springs are small, but here and there in the world are very large ones. These usually occur in level ground, the water coming from rains on the hills or mountains. Some of the largest springs in the United States include those in northern Florida, at Tuscumbia, Alabama, and the great spring at San Marcos, Texas.

A hot spring is the outflow of water which has passed over hot rock, usually lava, situated at considerable depth below the surface of the earth. The hot water is more likely than ordinary cold water to contain minerals in solution, and for that reason many hot springs are valued—many of them over-valued—for medicinal purposes.

Valleys of various kinds

A valley is a depression of one form or another between mountains or hills. The typical valley is relatively narrow, well watered and fertile. Most such valleys have been carved by streams, sometimes also molded by glaciers. The word valley is sometimes used for narrow depressions or widened mountain gorges. Again, the term valley is applied to very large tracts of land, more or less level, in which the depression is not too wide for one to see across.

How our prairies were made

A prairie is a level region usually in a district over which a continental glacier has passed, and which has been covered for centuries with a growth of tall grass. The decay of this, together with carbonates derived from the rocks, gives the region a rich, fertile, black soil, in which most forest trees do not readily grow, unless the soil is modified by cultivation. In prairie regions, forests are native chiefly where the black soil has been washed off from elevations or where, on banks of streams, it has been carried away by erosion. The word "prairie," which in French means "meadow," is applied mainly to the great district extending from the Peace River in Canada, south to about the latitude of St. Louis, east to Indiana, and west nearly to the Rocky Mountains. The states of Iowa and Illinois are composed almost entirely of prairie.

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MESA COUNTRY

Typical mesa country in the vicinity of Tucson, Arizona. Mountains rise in the background. Note the large barrel cactus in center foreground and a number of branching treelike cacti in the background.

Steppes—Russian prairies

Steppe is the Russian name for the great areas in southern Russia, resembling our American prairies, but, from lack of rain and for other reasons, less fertile and having less vegetation.

Pampas—Spanish-American prairies

Pampas is a Spanish word meaning "field" or "plain," and is applied to the large prairies of Argentina and other parts of South America. These regions, for the most part, have rich soil, and are covered with a rank growth of tall "pampas grass."

Plateaus and mesas

A plateau is a nearly level tract of land, often of large extent, elevated above surrounding regions. Mesa, a Spanish word meaning "table," is applied to level tracts, usually small, which have been left standing, the surrounding country having been eroded away. In a mesa or table-land, the surface rock is usually harder than the deposits below. Hence, it remains standing after the surrounding materials have been washed away.

The "staked plains" of Texas

Llano is a Spanish word for plain. In the United States the name occurs in Llano Estacado or "staked plain," of Texas. It is said to have received its peculiar name from being apparently staked out, that is, surrounded on the south by fences of rocks.

Rivers and their mouths

A river is a large natural stream of water flowing to or toward the sea, or, in some cases, into salt lakes without an outlet. Most rivers rise in a multitude of springs, which give rise to small streams, these joining finally to form rivers. The longest river in the world is the Missouri-Mississippi. It is 4,200 miles from the source of

the Missouri to its mouth in the Gulf of Mexico. The largest river is the Amazon, in South America, which drains a large portion of that continent. Its length is about 3,500 miles.

A delta is a broad level plain, shaped approximately like the Greek letter (△). It is formed by material washed down by a river into the sea. The name was first given to the plain formed at the mouth of the Nile, but many other great rivers have deltas.

Floods in various places

A flood is a great excess of water. This may be due to any one of various causes—especially, to rain or to melting snow. A flood tide is the incoming rush, twice every day, of water from the sea. A flood plain is a level area overflowed by a river in its period of high water, arising from rains or melting snows.

Swamps or marshes

A swamp or marsh, is a tract of land covered with standing water, which is, however, shallow, and does not prevent a growth of trees, grasses or sedges. A swamp differs from a bog in its lack of peat-forming moss, which is replaced by a variety of trees, bushes and other vegetation. Large swamps are often formed in flat areas in the coastal plains which have imperfect drainage. Among the noted swamps in the United States are the Dismal Swamp around Lake Drummond in Virginia and the Okefinokee Swamp in Georgia and Florida. Still more extensive is the swamp called the Everglades, covering a large part of southern Florida, crossed at intervals by ancient coral reefs, which show that the swamp was once a part of the sea. It is true, of course, that once, countless ages before Florida existed, all parts of the earth were under the sea, as is shown by the fossils, especially of sea shells, which occur in almost all deposits except those which have been subject to metamorphosis (change), that is, which have been melted wholly or partly, in the changes that go with mountain forming.

The treeless swamps that are called bogs

A bog is a wet area, largely filled by vegetation, not timber, occurring in most cold regions. The word belongs properly to a class of treeless swamps especially common in Ireland. In the last glacial period, many thousands of years ago, the glaciers scooped out and deepened many valleys, large and small, leaving, as the ice finally melted, multitudes of lakes and ponds. These constitute the vast majority of ponds of today. But thousands of these have become filled up by vegetation and have become either swamps or bogs or sometimes "rolling prairies." This is true in all regions where the glaciers have long since passed away.

Peat bogs

The transformation of ponds into bogs is started by a rootless moss, called sphagnum, which grows upright in the water, close packed, about a foot in height. As the stem of each plant grows higher and higher, an equal part at the base dies and drops to the bottom. Cranberry, swamp laurel and other delicate vines soon bind the mass together, so that it forms a floating carpet on the surface of the water, and is known as a "quaking" bog. The vines hold the surface moss in place. Little by little, the droppings of the sphagnum fill up the pond, and, after the lapse of centuries, become solidified to form an imperfect coal called "peat." Trunks of fallen trees are often more or less embedded in the peat, but the bulk of it comes from the dropping stems and leaves of the sphagnum.

In districts where the peat serves for fuel, it is cut out in blocks and dried. It is used in Ireland, Russia, Scotland and Scandinavia, but nowhere else in the world does it figure so largely in the life of the people as in Ireland.

How a bayou is made

A bayou is a narrow, blind lane of water which once was part of an old river channel, but which has been closed at one or both ends by deposits made by the river. Usually it is a sort of long, narrow, often curved pond, left when a river changes its course. In the lower Mississippi Valley, where the banks are very low, such changes have been common, and it is chiefly in Louisiana that the name bayou is used.

Trade winds

Trade winds are drying winds blowing continually in the same course or "trade" (from an old meaning of the word signifying "course" or "path"), toward the equator from an easterly direction. They are produced by the rotation of the earth and the movement of air toward the equator to supply the hotter, rarer air which arises there. Trade winds in the northern hemisphere blow from the northeast; in the southern hemisphere, from the southeast.

These winds are very regular, especially over the oceans, where there are no disturbing influences from great land masses. Since the trade winds are quite permanent they are of great value to navigators.

INDIANA SAND DUNES

The shifting sand dunes of northwestern Indiana are noted for their beauty. This region is a favorite one for recreation and outings. A portion of the dunes country is a state park.

Drifting hills of sand—dunes

A dune, or down, is a hill of sand near the seashore or along a large lake or river. It is made of wind-blown sand, and, when established, moves slowly as the sand is blown off the wind side and deposited on the lee

TWO SCENES FROM THE IMPERIAL VALLEY OF CALIFORNIA

The patch of prickly pear cactus is typical of this area when it is a worthless desert. By irrigation, man has made possible scenes such as the one on the right—harvesting a splendid crop of lettuce.

side. Nearly all sandy shores have dunes in some degree.

The great dry waste places—deserts

A desert is a region nearly or quite barren, being nearly rainless. It is characterized by scant vegetation, largely dry and thorny, and often by masses of drifting sand. Deserts occur in tropical or semi-tropical regions. They vary much in character and extent. If furnished with water by irrigation, they may often be made to "blossom like the rose."

A large part of Palestine was desert until irrigation became established. The valley of the Great Salt Lake, which bears a striking resemblance to that of the Jordan River and the Dead Sea, was brought to great fertility by the Mormons, the first permanent settlers of Utah. Even more striking is the great Imperial Valley of Southern California, a worthless desert until reclaimed by a canal connecting with the Colorado River.

The wonders of caves

A cave is a large opening in a rock mass. Many caves represent ancient courses of underground streams which have dissolved and worn their ways through limestone rocks. Carbonate of lime is slowly soluble in water, and any water which falls into a limestone deposit is likely to form some sort of a cavity, into which a stream may fall. Once established, the stream is likely to drop later to a lower level, leaving its higher reaches empty. Some caves are open at the mouth only; some are formed by the union of many branches; some cavities not produced by water are locally known as caves. Many caves have been inhabited by wild animals, bears, wolves, foxes and the like, and some also by primitive man. In a few cases (as in Mammoth Cave, Kentucky), the original stream has not disappeared. In some cave streams, perpetually without light, are found blind fishes, blind salamanders, blind crawfishes and blind insects. In most caves bats gather in daytime, sallying out at night in search of their insect prey. When a cave "caves in" through weakness of its roof, it creates a "sink hole" in the surface of the ground above. Many of these are found in Indiana and Kentucky.

When water drips from the roof of a cave, the lime in solution is deposited as the water evaporates. This produces an icicle-like formation, called a "stalactite." Water falling to the

floor deposits its lime in a shorter and thicker mass, called a "stalagmite." In time the stalactite and the stalagmite may unite, forming a column.

The most noted of all the myriad caves in the world is the Mammoth Cave of Kentucky. This has not been completely explored, but men have gone through so many of its branches that we know it is ten miles in extent and contains more than 200 miles of avenues, channels, pits and domes. One of its grottoes, called "The Temple," is over 500 feet long, about 30 feet wide, and 125 feet high. Mammoth Cave is one of a large system of caves occurring in an area of about 8,000 square miles in Kentucky, Tennessee and Missouri.

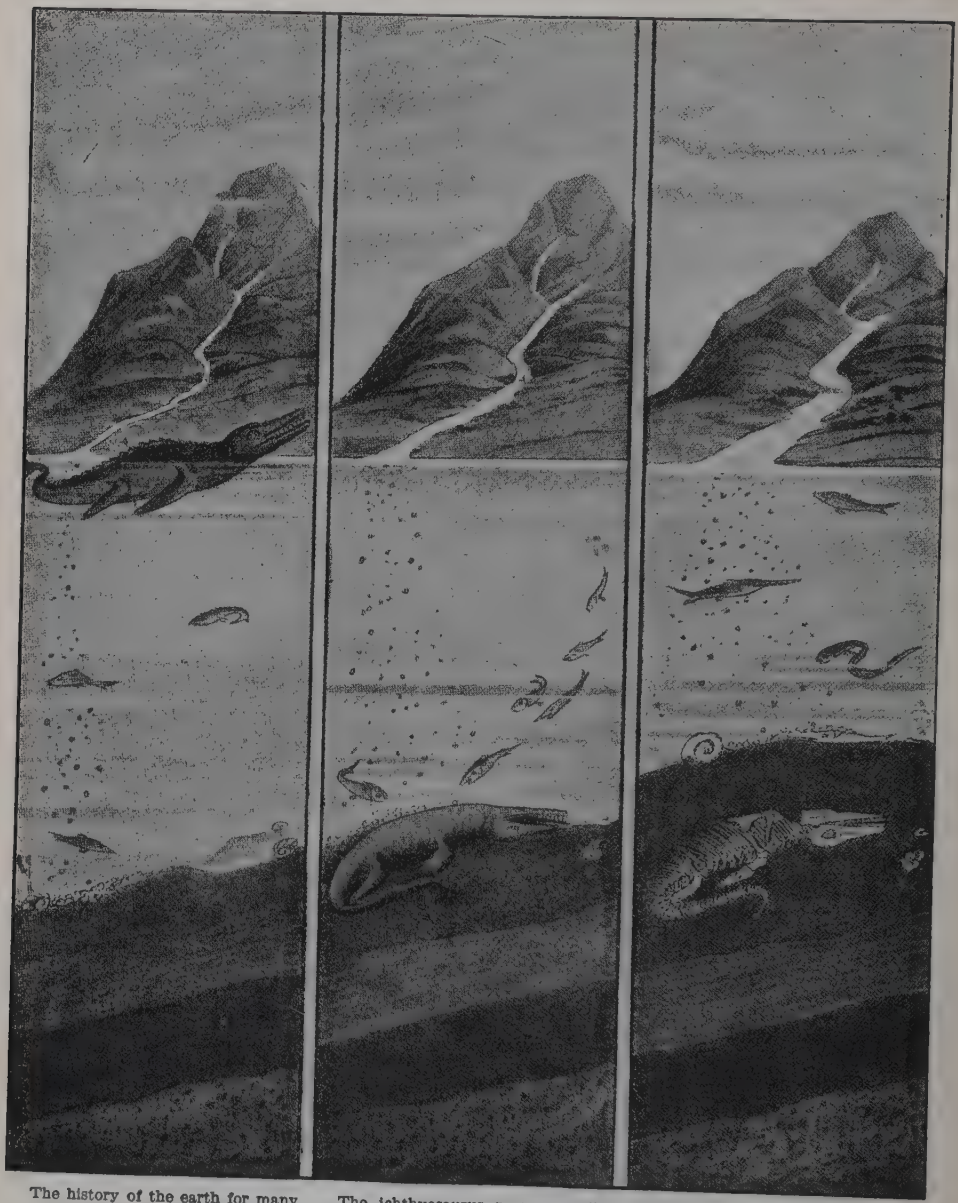
The Wyandotte Cave of Indiana is about twenty-three miles long. It is famous for its remarkable crystals, whose beauty is said to exceed that of the formations in Mammoth Cave. Among the features of Wyandotte Cave are the Pillared Palace and Monument Mountain.

Still more remarkable than either of these is the Carlsbad Cave in New Mexico. This contains amazing chambers, together with pillars, stalactites and stalagmites in bewildering abundance; with these are also many valuable relics of the men who were its primitive inhabitants.

We have told something of the geology, or earth story, which underlies all geography. To describe it all in detail would take dozens of big books. Every American should know the mountains, gorges and waterfalls of his own land. It is the plain road to real Americanism, so well indicated by that great lover of the out-of-doors, John Muir, who said, "I tread the crust of the earth in adoration."

THE BIG ROOM, CARLSBAD CAVERNS ©*Santa Fe System Lines*

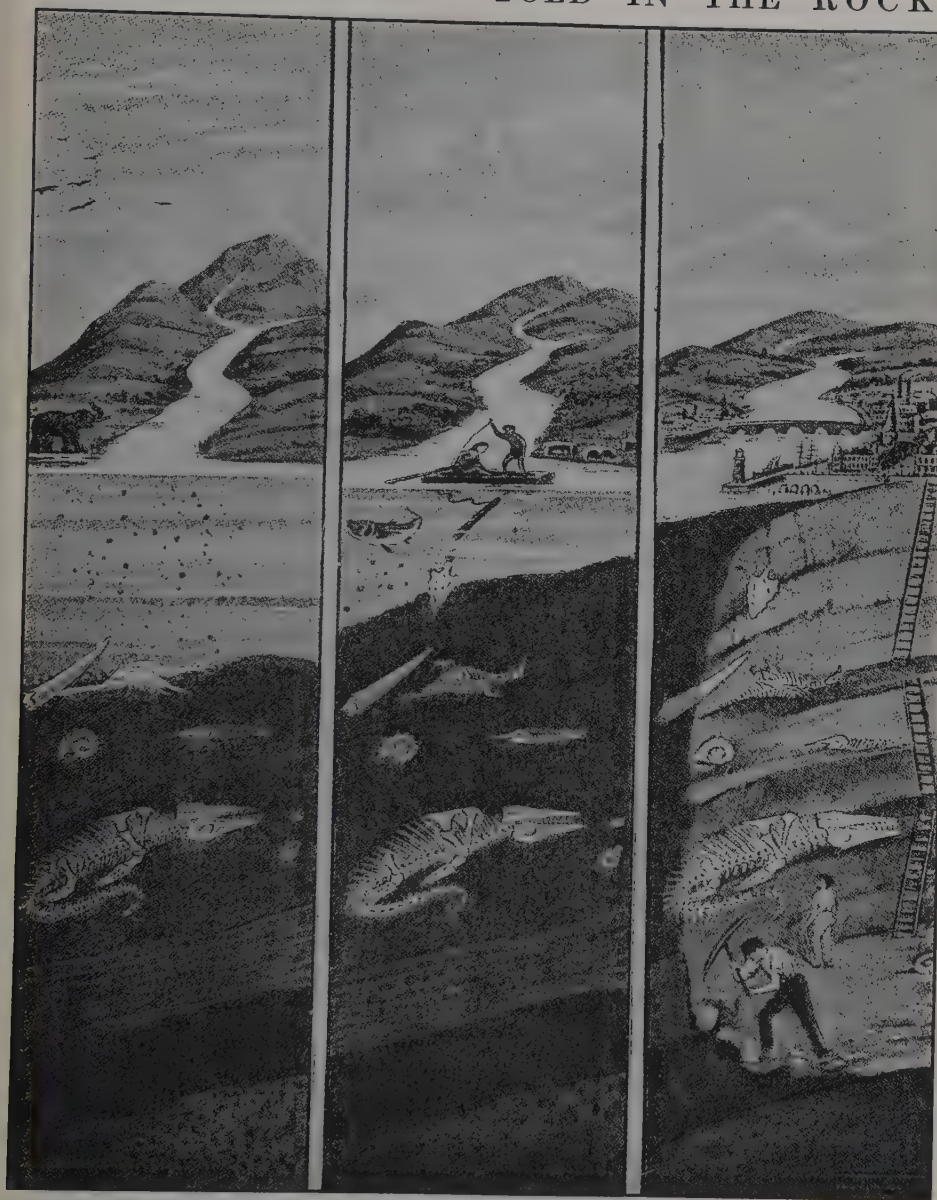
The Carlsbad Caverns in New Mexico surpass all others in the size, beauty and variety of decorations. Here are shown a graceful group of "Totem Poles" in the Big Room, which is more than three-fourths of a mile long.



The history of the earth for many years is written in its rocks, and men are able to read what took place, and to give us, in pictures like these, a vivid panorama of the earth's long wonder-story. We can see also just how that story came to be written in the rocks. Years ago, a little stream trickled down a mountainside, carrying with it grains of sand, gravel and stones, which fell to the bottom of the sea. In the sea swam a great and wonderful creature called an ichthyosaurus.

The ichthyosaurus was a reptile that lived in the sea, and its name means "fish-lizard." It had a great head with powerful jaws and teeth, and its body had four limbs like paddles which enabled it to swim about. One day the great creature died, or probably it was killed in battle with another strange monster, and its body fell to the bottom of the sea among the shells and seaweed. Meanwhile, the stones and sand brought down by the stream continued to fall upon the bed of the sea.

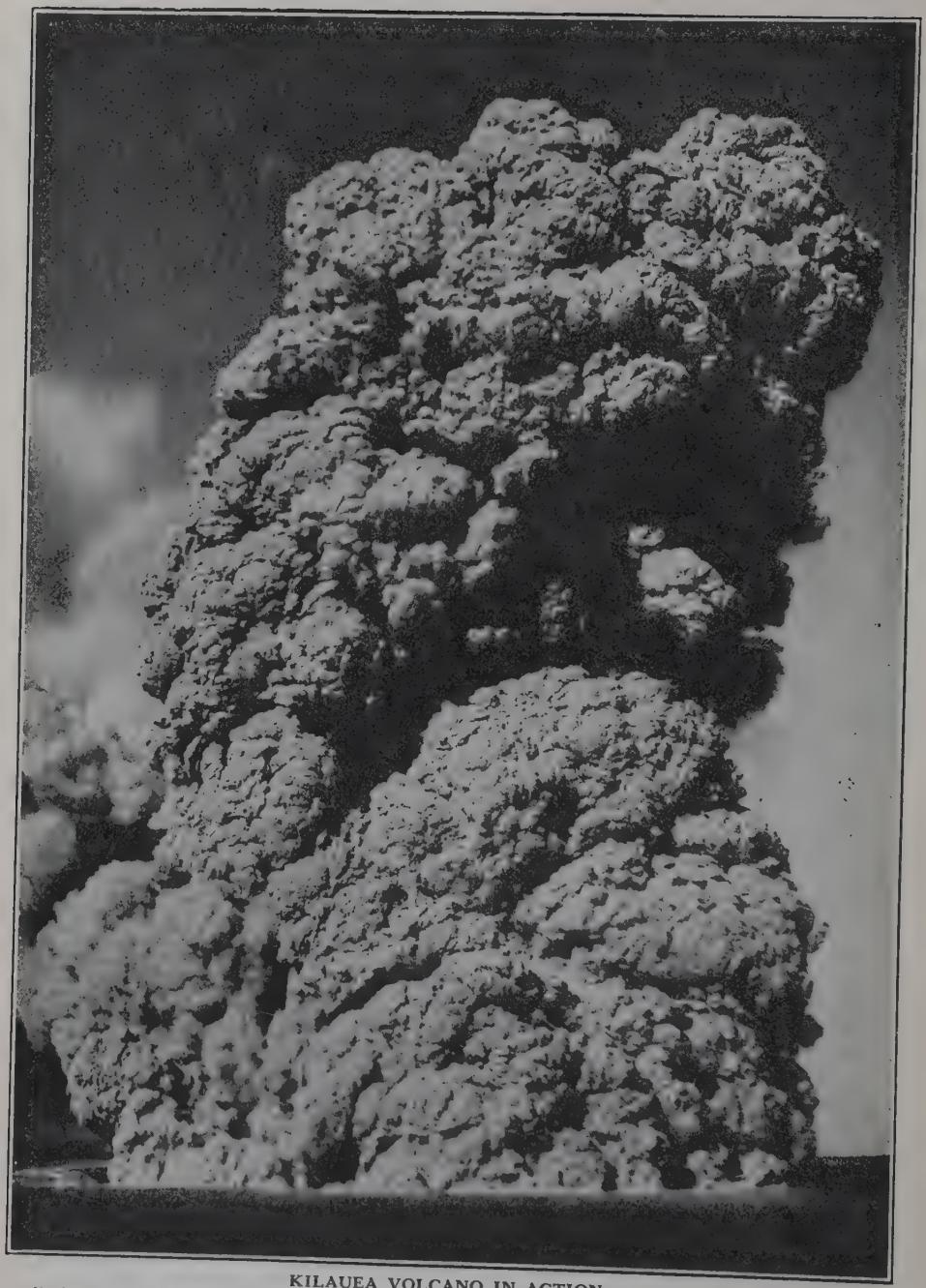
As the ages passed, the stream gradually wore away a wider and deeper bed for itself, and became a big river; and the rains falling upon the mountain loosened the soil and formed hundreds of tiny streamlets. These all ran into the main stream, and each did its part in wearing away the mountain. As the river became wider, so it brought down more and more earth and stones, which fell in a never-ceasing shower upon the bed of the sea, until at last the great reptile's body was buried.



Higher and higher rose the ocean-bed as the mud from the mountain continued to fall upon it, and the lower layers became pressed into hard rock by the weight on top. One day an elephant going to the river to drink broke off his tusk, and this was carried down by the river and sank in the sea. Another day a bird was drowned, and this, too, fell upon the ocean bed. Dead fishes and shells also sank, and all were buried by the never-ceasing shower of mud and earth and sand and stones.

All through these ages the rain and river were wearing the mountain away. And then, thousands of years after the ichthyosaurus died, men began to live on the earth, and one day a man who had made a boat out of a hollow tree trunk took his wife and went out to fish. Trying to spear a big fish, the head of his harpoon broke off and fell to the bottom of the sea. It was too far down for the man to recover it, and in course of time this also was buried in the mud.

The bottom of the sea crept higher and higher, till at last it became dry land. Then one day men began to dig, and the world's wonderful story was revealed as we read it here. First the spear-head was found, then the tusk, the bird's skeleton, the shells, the fish, and at last the skeleton of the great sea reptile, all turned to stone and become fossils, a word that means something dug up. It is hard to realize that these fossils found in the rocks were once living, moving animals.



KILAUEA VOLCANO IN ACTION

Explosions on the morning of May 24, 1924, making what is called a "cauliflower" cloud. It was a cloud like this that accompanied the terrible eruption in St. Vincent in 1812.

MOUNT EGMONT, NEW ZEALAND—A TYPICAL LAVA CONE
It is characteristic of this type of mountain to have side shoulders, which are the remains of former volcanic cones.

EARTHQUAKES AND VOLCANOES

IF you sit on a hill top on a still August evening, with the insects humming and the sky rosy, the world and the universe are standing still; only the little flies and the light winds are moving. The moon for you is not a ball; it is a crescent window to the heavenly light behind the sky.

THE GALLOPING UNIVERSE

But things are not what they seem. By slow experiment man has proved that the solid hill rises and falls every day with a rock tide, that the sandstone ledge was once a seabeach, that the shore line even now is heaving up gently through the years. We know that the mountains may jump sideways as at San Francisco during the earthquake, that the earth was once all volcanic paste, hot and molten and mobile, and that sun, earth and moon are merely parts of a tiny star-family moving within a gigantic wheel-shaped cloud of stars that we see edgeways when we look up at the Milky Way.

The whirling earth-top is spinning our hill like a big dynamo and the evening breeze is part of the disturbed air. The hill is moving from west to east around the earth axis seventeen miles a minute. The globe that holds it is moving around the sun at the rate of 1,080 miles per minute—1,100 times faster than an express train. Down and up, right and left, west and east, around the sun, shrinking, expanding, heating, cooling, dissolving—our hill is anything but placid and still. Our peaceful sunset hour is *only an hour*. By days and centuries the hill is part of a mightier procession of changes than the story of mankind from the dawn of history to the present. Lengthen the hill farm into billions of square miles out into space—

> "Beyond the bounds our staring rounds,
> Across the pressing dark,
> The children wise of outer skies
> Look hitherward and mark
> A light that shifts, a glare that drifts,
> Rekindling thus and thus;
> Not all forlorn, for Thou hast borne
> Strange tales to them of us."

THE LIVING EARTH

Thus the earth is alive. Everything is in fast motion, even the tiniest particles of solid matter, like little solar systems. We ourselves are living in a famous geologic age right now; it is the end of a glacial period; Greenland and Antarctica are still all covered with ice. It is an age with tremendous deserts. It is an age of insects and bacteria, and we do not know at all surely whether man will win in the war against them.

This article, prepared for *The New Human Interest Library* by Dr. T. A. Jaggar, formerly Volcanologist, Hawaiian Volcano Observatory, U. S. Geological Survey, is published by permission of the Director of the U. S. Geological Survey.

The whirligig earth was once liquid and sizzling with gases. If you spin a globule of oil in alcohol by means of a wire through its center, it will fling off little round drops of itself that will gently circle around the ball of oil. So the earth and Venus and Jupiter were flung off the revolving sun. Next the earth flung off its baby globe, the moon.* Lava was the principal ingredient of both, except for vast quantities of burning gas. The moon, being smaller, cooled and crusted the faster, and its crust became covered with lava lakes. Each of these became circular around the hole that fed it with gas and lava. And then through the ages the moon cooled and lost its gas to the earth. Earth and moon moved apart with much slowing up of their relative motions. Now with a field glass we can see the round craters on the dead moon.

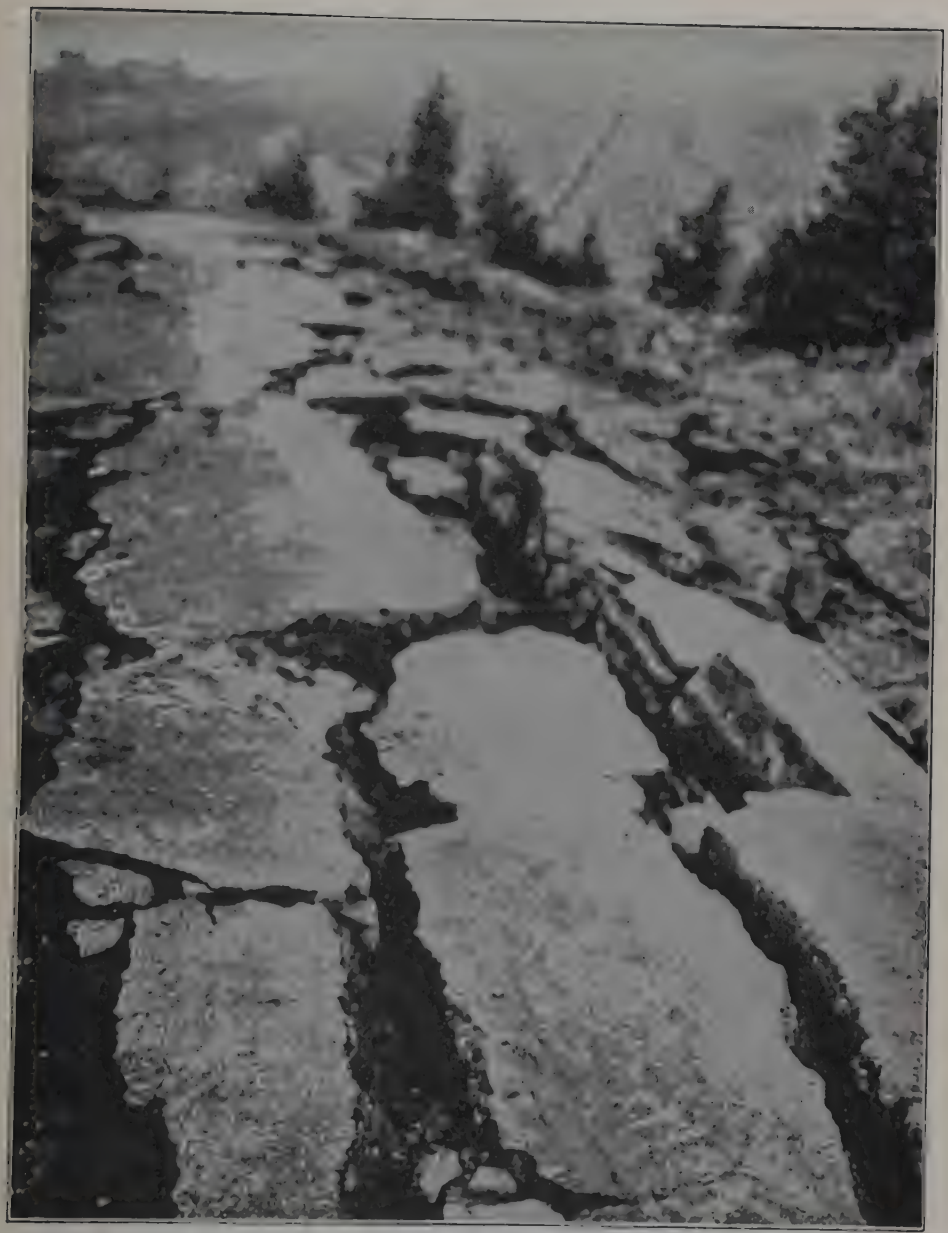
But the earth was doing the same volcanic erupting and on a bigger scale. Earth and moon had learned the habit from the sun. The sun today has gas eruptions a hundred thousand miles high which change shape in a few hours. The earth cooled more slowly than the moon and nursed a blanket of its own gas on its outside. The earth, too, was covered with big and small lava lakes, round saucers with walls 30,000 feet high. If you look at Java and Sumatra on a globe you will see that they make, with other islands, a big circle of volcanic lands, with seas inside and outside, and the volcanic Philippines in the middle. Perhaps this Java-Sumatra area is a remainder of one of the lava basins of the earth as it first became solid.

THE IMPORTANT PART PLAYED BY ERUPTIONS

The sun was throwing off gases, the moon was throwing off gases. The erupted gas of earth and moon made our air. The gas was full of steam that condensed to make our ocean. And then the earth in becoming solid had regular tides and cycles of heating and cooling, throwing off gases and crusting over. These tides and cycles, in days and hundreds of centuries, still continue everywhere. The rocks thirty or fifty miles down are everywhere merely hot lava, full of gas ready to break out. Within volcanoes this stuff *is* erupting because the cracks in the crust are open and letting it out to add new gas to the atmosphere and new rock to the land. If we travel to Vesuvius or Hawaii, we can see and collect specimens of the original sun matter at work in one of the cooler stages, just as the astronomer sees it in a terrifically hot stage when he points his telescope to the edge of the sun.

As these erupting stages were taking place, continents were being formed. First the lands were high volcano domes and circular ramparts that joined in large groups and were left standing high, while bigger tracts of water-covered land remained. Low and high are very small quantities as compared to the size of the earth ball, for, from the top of a peak 20,000 feet high down to sea level, straight up-and-down, is only a thousandth of the distance to the center of the earth. The earth in those early millions of years of its babyhood was like a big engine hitched to the sun and moon. It had its game of ring-around-the-rosy with the moon. They both got tired and slowed down. It had to obey its big mother, the sun, and it had to obey the cooling waters on its surface, shrinking in one place, swelling in another, while the air and steam made furious storms.

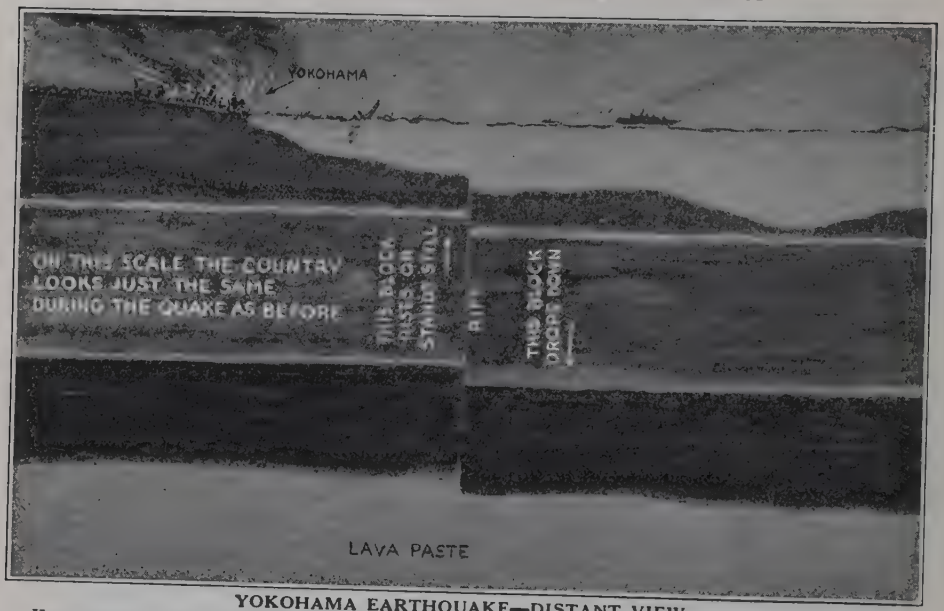
*Some scientists disagree with this theory which is simply the author's best guess. The same situation holds for many other statements which must remain as unproved theories. —Editor.



SPLITTING THE EARTH'S CRUST

This picture was taken in the fall of 1923, sixty miles south of Yokohama, Japan. It shows how the road was cracked into deep fissures from the shock of the mighty earthquake near Numadzu, in the Suruga province.

The floods of volcanic mud and steaming torrents loaded with grit filled up the first shallow seas. The waters covered the places least filled up. Thus there came into existence thin layers of rock made of mud and sand and cemented pebbles, thrown up from the filled seas.


YOKOHAMA
ON THIS SCALE THE COUNTRY LOOKS JUST THE SAME DURING THE QUAKE AS BEFORE
THIS BLOCK RISES OR STANDS STILL
RIFT
THIS BLOCK DROPS DOWN
LAVA PASTE

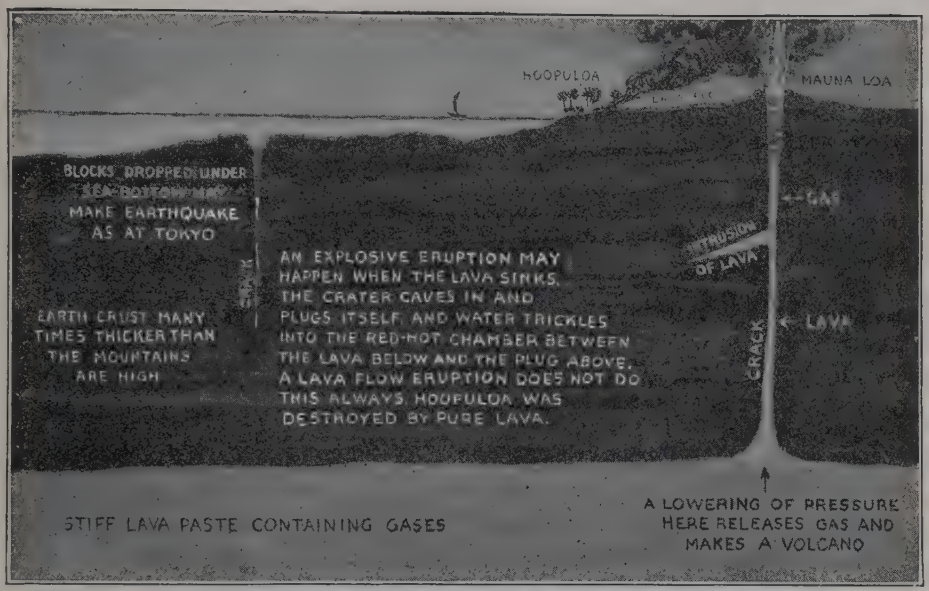
YOKOHAMA EARTHQUAKE—DISTANT VIEW

Here we see at a glance what happens during an earthquake. Deep within the earth something—we cannot with certainty say what—gives way. We cannot tell just *how* the earthquake is related to the deep-lying lava paste. Blocks of the earth's crust move up, down or sideways, grating against each other in what we know as an earthquake.

During the Yokohama earthquake whole mountains rose from two to eight feet and the bottom of the bay dropped, as shown with exaggeration by the artist. The scene here illustrated extends over several hundred miles and the earth's crust is many miles in thickness.

YOKOHAMA EARTHQUAKE—IN THE MIDST OF THE DESTRUCTION

A great city had been built at Yokohama. When the earth moved there came a crushing destruction; buildings slumped; the wharf cracked open; the street was thrown into waves; people and automobiles fell into yawning cracks, some of them four feet across. Dust arose; fire followed, and people rushed into the sea to escape the flames.


HOOPULOA
MAUNA LOA
BLOCKS DROPPED UNDER SEA BOTTOM MAY MAKE EARTHQUAKE AS AT TOKYO
GAS
INTRUSION OF LAVA
AN EXPLOSIVE ERUPTION MAY HAPPEN WHEN THE LAVA SINKS. THE CRATER CAVES IN AND PLUGS ITSELF AND WATER TRICKLES INTO THE RED-HOT CHAMBER BETWEEN THE LAVA BELOW AND THE PLUG ABOVE. A LAVA FLOW ERUPTION DOES NOT DO THIS. ALWAYS HOOPULOA WAS DESTROYED BY PURE LAVA.
EARTH CRUST MANY TIMES THICKER THAN THE MOUNTAINS ARE HIGH
CRACK
LAVA
STIFF LAVA PASTE CONTAINING GASES
A LOWERING OF PRESSURE HERE RELEASES GAS AND MAKES A VOLCANO

MAUNA LOA VOLCANO IN ACTION—DISTANT VIEW

Many miles below the surface of the earth, in a gas-laden lava paste, there is a lowering of pressure and a release of gas. Penetrating through a crack in the earth's crust, out comes the lava flow. Rocks are rent asunder, molten lava and fiery tongues of burning gas issue from the crater of the volcano.

The artist has depicted the actual happenings at the time Mauna Loa destroyed the little Hawaiian village of Hoopuloa. The illustration represents an expanse of several hundred miles. The crust of the earth is many miles in thickness.

DESTRUCTION OF HOOPULOA—NEAR VIEW

The irresistible fiery stream of lava poured down from Mauna Loa Mountain burning house after house with the glowing stones that came in the volcanic torrent. Compare this artist's drawing with the actual photograph shown on Page 40.

Some guesses about geography

No one knows how the continents were first formed. One guess has it that the moon, when it separated, left a great hole on the Pacific Ocean side of the globe; that is, a part of the earth was ripped off and rolled up into a ball to make the moon. The crust that was left may have broken into blocks, like icebergs in the arctic seas in springtime. As the earth revolved from west to east, these blocks slowly moved from east to west over the layer of pitchy lava in an effort to heal the Pacific Ocean wound.

The first continents to separate were North and South America. These parted from Asia, Greenland, Europe and Africa like the pieces in a picture puzzle; and if we were to shove them back, North America would close up the Arctic Ocean and the North Atlantic, the east point of South America would fit very nicely into the Gulf of Guinea, and so forth. But all these guesses are only amusing; they are not proved.

Weighing hills, plains and islands

What *is* proved is that the sea-bottom rocks are heavy and the high mountains are light. This would make the mountains, plains and sea-bottoms all floating on that layer of red-hot stiff lava-glass below. And the heaviest blocks have sunk lowest. With nicely adjusted instruments we can weigh a hill, a plain or an island.

The struggle between volcanoes and mud

So the volcano highlands of heavy lava may have slowly changed places with the basins filled with comparatively light clay or sand and with water. Thousands of feet of these sediments were heaved up into table-lands, worn away into valleys and mountains, and the debris dammed up the volcanic cracks and craters. The volcanoes were left in the deeper oceans and along their borders; over the land the volcanic forces were buried deeper and deeper under mud and lime. The volcanic force of heat and expansion and gases was given over to making hot springs and minerals and lava in cracks. Today these old volcanoes are buried in a hundred places. We find their ancient lavas near New York and San Francisco, near Montreal and in Texas, in Rio Janeiro and Edinburgh. When a big and unexpected earthquake occurs, we suspect that the volcanoes are not really dead.

How the Pilgrim Fathers met earthquakes

We do not usually think of the Pilgrims, with all their hardships of Indian fighting, as encountering earthquakes in quiet old Plymouth. Nevertheless, in June, 1638, a great and fearful earthquake came with a low murmur from the north, heard before it was felt, and passed to the south. In Plymouth, as the noise came nearer, the earth shook until platters and dishes on shelves clattered and fell down. People feared for their houses, even strong wooden cabins.

The earthquake of New France

In January, 1663, there was in "New France," now called Quebec, an earthquake so tremendous that it broke chimney tops in distant Boston. It cracked up the Canadian country, shook down landslides and dammed creeks, and made such roarings and shakings that people threw themselves on their knees and cried out for mercy. Trees were uprooted, the St. Lawrence River was white with mire for months. Indians paddled their canoes through new waterways cracked open through the land, and the sides of the Saguenay River were changed. Canada entered on a shaking period and kept it up for six months.

PEOPLE, NOT EARTHQUAKES, MAKE DISASTERS

An earthquake is nothing more than the heaving and breathing of the living volcanic earth. A buried volcano may begin to show activity and adjust the crust of the earth to a more comfortable position. An earthquake need not be a disaster. There are colossal earthquakes that harm no one. They shake down mountain sides and heave up the rocky shore, make cracks across country or along the sea-bottom, and drop down whole blocks of sea-floor hundreds of miles long. Or, they may choose a place like northern Alaska or mid-ocean, where no one dwells. To understand disasters, we must realize vividly the growth of peoples, spreading like big clusters of grapes on a creeping grapevine of history, all over the world. Cities are what make catastrophes. Through four or five thousand years man has been learning the advantages and disadvantages of crowding. Our age is an age of organized crowds. "Business" needs crowds and the crowds need business. Out of this there arises the factory, the port and the market place, where spring up cities.

In 1776 the United States was a little strip of country from Maine to Georgia; in 1783 it reached the Mississippi; in 1803 it touched the northern Rockies; in 1845 it had crossed the great plains everywhere; in 1846 it took in Puget Sound; in 1853 it had spread down across California and Nevada; in 1867 it embraced Alaska; in 1899 it swallowed the Philippines, Hawaii, Samoa, Guam, Panama and Porto Rico, including big cities, and Americans in business had spread over the quaking and volcanic lands of the whole world.

The United States has been the greatest city-maker the world has ever seen. In 150 years it has grown to five times the area of the original thirteen colonies, and *they* had an expanse of 828,000 square miles. The march has been mostly westward, from quiet England into shaky Plymouth, and from shaky Plymouth into the liveliest volcanic lands on earth—California, Alaska, Hawaii, the Philippines and Porto Rico. So when you read of the newest volcanic disaster that has wiped out a whole city, remember that the volcano and the quaking were always there, but that the crowded city is the thing that is new and strange, placed where the builders knew not the story of the living earth.

AFTER THE EARTH TREMBLED

St. Nicholas' Church, Cartago, Costa Rica, after the earthquake of 1910. This earthquake came from the east like the crack of a whip jerking the ground sideways. Cartago is at the foot of a big active volcano, Irazu.

THE OWENS VALLEY EARTHQUAKE

In 1872, when California was young, a big earthquake at Lone Pine mining camp shook the whole state from Red Bluff to Los Angeles. About two hours after midnight, March 26, a terrific shock leveled the adobe dwellings of Lone Pine. The inhabitants numbered only about 275, of whom twenty-nine were killed and sixty wounded.

Dense dust hung over the valley. The miners underground saw the timbers rocking and came up to the surface. There were explosive subterranean noises, great landslides were dislodged and lakes were formed by the sinking of huge blocks of ground. At Owens Lake the water receded from the shore and piled up in a vast wave in the middle. The whole bed of the lake was tilted. The Owens River, which had been swift and deep, went dry by temporarily draining into newly opened fissures. Fountains of water spurted up new fractures. Along lines of fracture ten miles long, the valley moved down, and sideways—ten, twelve, twenty feet—strips of country dropped, others tilted. Possibly some deep mass of lava moved and made the mountains creak a little.

AN OBJECT LESSON

After the eruption of Sakurajima in Japan in 1914. Steep-roofed houses like these shed the fallen volcanic sand. Flat-roofed buildings were pressed down level with the ground and buried sometimes fifteen feet deep.

The earthquake was the creak. The San Francisco earthquake of 1906 was not very different, something giving way deep down under the whole length of the Coast Ranges and appearing at the surface in what is called the "rift." This is a crack or rupture more than 400 miles long where one side moved several feet north suddenly, the other side south. Out from the crack went the creaking noise and the creaking tremble. When whole mountains tremble and shake down the dirt on their sides and shake up the dirt in their valleys, the little ant hills we call cities must suffer.

SOUFRIÈRE VOLCANO

For some reason the earth gets tuned up to a quaky pitch at certain times, when volcanoes and earthquakes on one side of the world make a demonstration together. A remarkable crisis of this kind happened in America about the winter of 1812. Terrific earthquakes for three months upset the course of the Mississippi between Tennessee, Missouri and Arkansas; small earthquakes occurred in South Carolina; in early spring a frightful earthquake tumbled everything to a dust heap at Caracas in Venezuela, away across the Caribbean Sea; and finally the volcano, Soufrière, on the island of St. Vincent, in between the other places, erupted violently and disastrously, just as it had done ninety-four years before, and as it did ninety years later in 1902.

HOW REELFOOT LAKE WAS MADE

The changes in the Mississippi River made by the earthquake of 1812 produced Reelfoot Lake, some fourteen miles long by four wide, where before there had been dry land covered by forest. The land was sunk and flooded. Thousands of the dead stumps still project above the surface of the water. Fires since that time have swept from the shores outward through the closely crowded dead timber of the lake. Now the place is famous for its fishing and for the thousands of birds which congregate there. Thus an earthquake produced one of the great bird homes of the world.

A VOLCANO IN ACTION

On St. Vincent, a British colony with many Carib Indians and negro laborers, there were 200 earthquakes during the year leading up to Monday, April 27, 1812. On that day at noon there came a crash from the mountain, followed by a vast column of thick, black, ropy smoke above the crater. In this crater before, there were two lakes, and an inner hill of steaming sulphurous lava, mostly covered with vegetation. The eruption increased for three days, stones fell, fire flashed over the chasm at night, and at intervals there was a noise like the muttering of distant thunder. On Thursday evening the climax began; thunder clapped; electric flashes shot up like rockets and crosswise, red-hot rocks rose like shells in wartime, and finally fiery sand and burning gas boiled over the lip of the crater. This seemed to flow down above the mountain; it would roll back and then rush forward; it carried rocks and forests before it. What seemed balls of fire were hurled out of the furnace and some of them burst and set fire to bushes. In about four hours the glowing avalanche reached the sea. After midnight another such burning cloud poured over the crater rim, and rolled down the opposite side of the mountain.

HURLED BY KILAUEA

This boulder, weighing eight tons, was thrown 3,000 feet from the pit of Kilauea Volcano on May 18, 1924. In the background is shown the dust cloud rising from the pit that had ejected this boulder.

There was a roar; the earth shook; hot stones fell on roofs, and the rumbling, trembling and blinding discharges from the crater reached a point where terror gave way to despair. Houses were fired by the fall of glowing pumice stone. This dreadful rain lasted an hour. People sought shelter in cellars, under rocks, or anywhere; and the miserable negroes, flying from their huts, were knocked down or wounded, and many were killed in the open air. Then cinders came instead of stones. Earthquake followed earthquake as though the whole of this part of the island were moving in waves. The dawn was black darkness. After eight o'clock the sulphurous clouds were barely visible. Trees and houses and hills were covered with rocks and sand and dust. Friday afternoon the muttering of the mountain sank gradually into a solemn silence.

VOLCANO AT NIGHT

Looking down into the lava pit of Kilauea Volcano. Black crusts appear on the rear pool, and bursting fountains of lava in the foreground.

WHEN MAUNA LOA BOILED OVER ©*Tai Sing Lao*

The destruction of the Hawaiian village of Hoopuloa, 5:15 A. M., April 18, 1926. In connection with this photograph study the diagrams on Page 35.

THE DESTRUCTION OF HOOPULOA

In 1926, the dome-shaped volcano, Mauna Loa, in Hawaii, destroyed the native village of Hoopuloa. It did this without any big explosions. Suddenly a brilliant light was seen, in the night, over the top of the mountain. Cracks in the ground had opened; burning gas had flamed up, and lava froth came with the gas. Then the same crack spread itself ten miles down the big flat mountain. Here a heavier lava came out in fountains, flowed twelve miles down the slope to the sea, and in two days reached the little village of Hoopuloa with its wharf and about ten wooden houses, most of which belonged to Hawaiian fishermen. The lava formed great lumps like snowballs, and down the middle came a slow, fiery stream. On the flat by the village it lingered a whole day, piling up in a stiff puddle of red-hot slag. Then it cruelly pushed on into the harbor, burning one house after another with the glowing stones that tumbled down its front. No one was killed, but the poor people sat about and watched their homes burn and become buried. Fish were killed by thousands when the hot rocks entered the sea. Every house in the unfortunate village was destroyed.

HOW WE ARE LEARNING TO SAVE PEOPLE FROM THE WRATH OF THE VOLCANO

Typical volcanic eruptions occurred when St. Pierre was destroyed in 1902; when Vesuvius destroyed Ottajano in 1906, when Sakurajima devastated the beautiful Satsuma country of Japan in 1914, and when Kilauea in Hawaii threw up rocks and sand to an immense height in 1924. So, in the twentieth century there are plenty of these eruptions for engineers to study, to see whether they can save the people by having them prepared.

And they are doing it by establishing volcano-study stations, by measuring very carefully the pulse and the temperature and the slow-changing height of the craters, and by advising, forewarning and guarding the districts that are in danger.

CUMULUS CLOUDS

Photographed in Washington, D. C. by the author of this article. The word *cumulus* is from the Latin and means "heap" or "pile." Many people call this cloud the "woolpack."

THE WEATHER

AS Mark Twain says, everybody talks about the weather, but no one does anything about it. It would be a safe guess, too, that not half of those who talk about the weather could tell exactly what it is. We speak of dry weather and wet weather, of warm weather and cold weather, of clear weather and cloudy weather, and of many other kinds; but what is *the weather*, this thing that everybody talks about, and that always is changing? It is the out-of-door temperature, wind, rain, or snow, cloudiness, and all other conditions of the air we see and feel, or can measure with instruments. In short, the weather, at any time and place, is the sum total of all the conditions of the atmosphere at that time and place.

Clearly, then, our comfort, our convenience, and even our success or failure in whatever we try to do, whether work or play, all depend, in great part, upon wind and rain, heat and cold, and everything else that renders the elements fair or foul.

"What is it molds the life of man?
The weather.
What makes some black and others tan?
The weather.
What makes the Zulu live in trees,
And Congo natives dress in leaves
While others go in furs and freeze?
The weather."

THE AIR

If weather is the condition of the air, what, then, is the air? It is the

Photograph by Buckingham

SUMMER CLOUDS

Beautiful alto-cumulus clouds, scattered like islands in the sky.

stuff we breathe and the thing that blows. All air behaves alike. That is why it seems to be a single substance. The chemist, however, can make many interesting experiments that prove the air to be a mixture of several entirely different gases, each one invisible and without odor.

The most abundant of these, amounting, in volume, to nearly four fifths of the whole, is *nitrogen*. We could breathe pure nitrogen and it would not poison us, but if we breathed nothing else we would be dead in a minute or two. Similarly, when we stick a burning match into pure nitrogen it goes right out, as if put in water. That is, nitrogen does not help to keep an ordinary flame burning, nor does it help to maintain life when breathed. It is, however, a fine fertilizer, in fact an indispensable one, but only when it has been coaxed or forced into combination with other substances.

The next most abundant gas in the atmosphere, about one-fifth in volume, is *oxygen*. It is this part of the air that keeps fires burning, and makes our breathing worth while. If all the air were oxygen, however, fires would be conflagrations, and life, if we lived at all, probably would be very different from anything we now experience.

Another necessary portion of the air, though only one to two parts in a hundred, is *water vapor*. Without this part of the air, from which we get all our rain and snow, the earth would be an utter desert, where neither plant nor animal could live.

Still another small fraction of the atmosphere, less indeed than one part in three thousand, without which no plants could live, is *carbon dioxide*, the gas that puts the bite in soda water and makes it foam.

One part, roughly, in a hundred of the air is *argon*, a heavy gas that leads a hermit life. It does not unite with other substances, and plays no part in the growth of plants or the fun of living. It seems to be just an innocent idler doing no harm and no good.

Finally, there are unimportant traces of many other gases that help to make the stuff we breathe exceedingly complex, and not at all the simple thing it seems to be.

This mixture of gases that we call the air has many properties, as the scientist calls them. For instance, it has weight. When we say that a thing is "light as air," we forget, perhaps, that just the small amount of air that fills an ordinary living room, say sixteen feet square and ten feet high, weighs about 200 pounds. No wonder then strong winds push hard, since checking a mere roomful of such wind would be like bucking a 200-pound football player in his dash for the goal.

The air, like all other substances, can be heated, but it takes about twice as much heat to warm a pound of air as it does to warm a pound of iron the same amount. As it gets hotter it also gets bigger, if unconfined. It expands, as we say, when heated, and contracts when cooled. It also has many other properties, but these are the chief ones that help to make and control the weather.

Measuring the weather

Our knowledge of a thing is best when we can say how much. If we want to know how tall we are, we are measured; how heavy, we are weighed; how fast we can run, we have ourselves timed with a stop watch. Similarly, if we want to be sure of the weather, we measure the several things that make the weather, and we record these values, too, or use instruments that make their own

LOFTY, FLEECY CLOUDS ABOVE THE FOG *Photograph by F. Ellerman*

Alto-cumulus clouds above a seething expanse of fog, Mt. Wilson, California.

WIDE-SPREADING ALTO-STRATUS CLOUDS *Photograph by F. Ellerman*

Clouds of this type extend over a wide horizontal area.

records, if we wish to know tomorrow what the weather was today.

We measure the temperature of the air with a good thermometer exposed outdoors to the wind but protected from sunshine. There also are instruments that keep a continuous record of the temperature on a sheet of paper moved by a clock and marked off in hours, or minutes, if desired.

The direction of the wind is found by a wind vane, so high above the ground that the wind at that level is not much disturbed by houses or trees. One can get this direction by noting the pointing of the vane, or it may be made to keep its own record.

The velocity of the wind can be measured and recorded in various ways, such as by the push it exerts, or the speed with which it makes a little windmill of some kind spin around.

The amount of rain that falls in a given time is measured by setting out a suitable open vessel a hundred feet or more from any house or tree and noting the amount caught in that time. Of course precautions are necessary, but it is clear that in this way one can determine very closely how deep the water that had fallen during this interval would lie on the ground, or, better, a smooth level surface, if none of it had soaked in, run off, or otherwise disappeared.

The humidity, or wetness, of the air is regularly measured by those whose business it is to keep a record of the weather; but while this measurement is easy and accurate, it is indirect, and its full explanation too tedious to make interesting reading.

The fraction of the whole sky that is clouded may be estimated, and the kinds of clouds noted.

While these are the more important, but not all, of the observations that together constitute the measurement of the weather as it is, there is another, which, though of little value for this purpose, is of the greatest use as an indication of what the weather of the next day or two is likely to be. This is the noting of the pressure of the air, usually and best measured with a mercurial barometer.

WHAT MAKES THE WIND TO BLOW

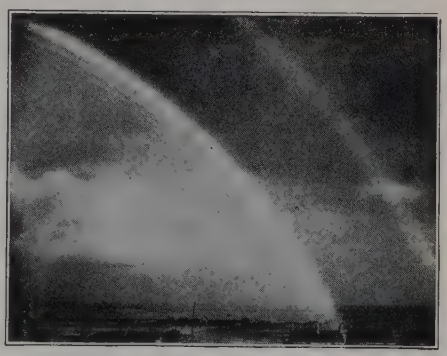
The only way to make anything that is not an animal move is to push it or pull it. We may get a dog to come by whistling, or go in a hurry by hissing, but the old sailor custom of whistling for the wind does not raise it a bit. Yet the winds do blow, and of course we want to know where the push comes from that makes them blow.

The air round about a burning brush pile, or other open fire, flows in to the hotter places and then up. This is a small wind. The air expands as it is heated, and therefore weighs less per cubic foot, say, than the nearby unheated air. The heavier, or denser, air then pushes the lighter air up, just as water pushes up a cork that is let go below the surface. The denser air, however, as soon as it gets in to the fire, is itself heated and expanded and in turn pushed up by the unheated air behind it, and so on, as long as the fire lasts. Now, although the winds of the earth, whether mere breezes or great storms, are not induced by fires, they are kept going in much the same way. Some portions of the earth, the tropical regions especially, are warmer than the others. Here, then, the air is pushed up like that over the open fire, by the cooler air from places nearer the poles. Now this warmest portion of the earth stays warmest, while the coldest stays coldest, hence the circulation of the air caused by this difference of temperature never ceases. It is not a

smooth and easy circulation, however, for there are many other portions of the earth that are unequally heated, and many high mountains to baffle the wind. Besides, and most important, these winds are flowing over a rotating earth. For all these reasons, and several more, the winds, though fairly steady over large stretches of the oceans, go by fits and starts, storms and calms, throughout the temperate and frigid zones.

WHENCE THE WEATHER AND WHY

As already stated, the atmosphere is continuously in a state of circulation between the equatorial and polar regions, by way of the relatively steady trade winds of the warm oceans, and the irregular storms of the cooler zones. That is, there is a continuous, however irregular, circulation of the atmosphere between the equatorial and polar regions, while the earth steadily rotates from west to east. If, now, the air were moving with the earth at the equator, as the drag of the earth on it tends to make it do, it clearly would run ahead of the earth, that is, blow from west to east, when it went to higher latitudes, unless somehow checked, because there the distance around the earth is much less than at the equator. Similarly, air that was moving exactly with the earth at high latitudes would lag behind the earth and appear as a wind from the east when it approached the equator. In fact this tendency is much greater than the mere distances around the earth at different latitudes would suggest, owing to what the scientist calls the conservation of angular momentum—and the name is much the easiest thing about it. Well, the upshot of the whole thing is a compromise. The earth runs ahead of the air a little from the equator to about latitude 30°, both north and south; then for a long way farther toward the poles the air runs ahead of the earth. That is in tropical regions the winds and the storms are mainly from the east, while in middle latitudes they are from the west, including northwest and south-



FIND THE POT OF GOLD

This picture shows both the primary (inside) and the secondary bows.

west—all, as explained, owing to the general north-south circulation of the atmosphere over a west to east rotating earth.

WHERE THE RAIN COMES FROM

Everyone knows that rain and snow come down from the clouds, and that clouds and fogs, which are exactly the same thing, consist of little droplets of water or crystals of ice. But there seems to be no end to this supply of water, for certainly it has been raining for thousands of years, and careful observations tell us that the total rain and snowfall over the whole world amounts to about sixteen million tons every second of time. Where does it come from and where does it go?

The wash on the line dries; puddles slowly disappear, even when formed in depressions on rocks where seeping away is impossible, and a thousand other like things occur that prove that water can and does evaporate—disappear as liquid water and become a part of the invisible atmosphere, from

which in turn it is condensed into clouds and from them precipitated as rain or snow. The answer to our question then is, the rain comes from the damp soil and growing vegetation, from rivers, lakes and the oceans; and to them it returns, a journey it keeps up forever—an endless cycle of evaporation and condensation.

"The mist and cloud will turn to rain,
The rain to mist and cloud again."
—LONGFELLOW

CLOUDS

When we get into a fog we know what a cloud is, for a cloud and a fog are exactly alike. We know then that a cloud consists of a vast number of tiny water droplets, or minute ice crystals, floating in the air. They are so tiny indeed, when water droplets, that if placed side by side in a row, it would take about a thousand of them to make a string an inch long, and two million of them to make a fair-sized raindrop.

Photograph by F. Ellerman
CIRRUS CLOUDS
These high, thin clouds are commonly known as "mares'-tails."

It was not until after the days of George Washington that people took enough interest in clouds, or saw, perhaps, enough difference in them, to give them special names. Now every type of cloud has its own name, and most of them have several names. That thin streaky cloud, often curled, and again looking like a giant feather, is called the *cirrus*, from the Latin word for "ringlet." Most of us know it as "mares'-tails." This is the highest and thinnest of all clouds. The beautiful summer clouds scattered here and there like islands, are called *cumulus*, another Latin word, meaning "heap" or "pile." Many people call this cloud the "woolpack." Similarly, various other types of clouds have both technical and common names, as fully explained and illustrated by beautiful pictures in any good book on clouds. But whatever the kind of cloud, it always is caused by the air getting so cold that it no longer can contain as an invisible gas all the water vapor that is in it. Some of the vapor then condenses as water on the thousands of foreign substances, such as dust particles, floating in the air, and the countless droplets thus produced make the cloud.

THE THUNDERSTORM

When the weather is hot and sultry, woolpack clouds often form in the sky, snow-white on the sunlit sides and blue-gray over the shaded portions. Presently one of these outgrows its neighbors and towers to great heights. Then rain falls from it and a thunderstorm is begun. This is the heat thunderstorm, by no means the only kind, but the most common.

The ground is heated by sunshine, and the warm surface in turn heats the lower air, causing it to expand and thus become lighter than the air not so heated. It then is pushed up by the heavier air, just as the warm expanded air in a chimney is pushed up

by the cooler and therefore denser air on the outside. As this lighter air is pushed up it gets colder, just as all rising air does, and if humid, soon produces clouds. When the air contains a

Photograph by Ellerman

LIGHTNING

Mt. Wilson, California.

large amount of moisture it often rises very rapidly within the cloud. This uprush not only forms raindrops, but dashes them about and tears them to pieces again and again. This rupturing of the raindrops produces the electrification that gives the lightning. This is why the lightning starts and stops with the fall of rain from the cloud.

The lightning so strongly heats the air along its path as to cause it suddenly to expand with great violence. This is the start of the thunder.

Said the cumulus cloud:

"I wield the flail of the lashing hail,
And whiten the green plains under,
And then again I dissolve in rain,
And laugh as I pass in thunder."

THE TORNADO

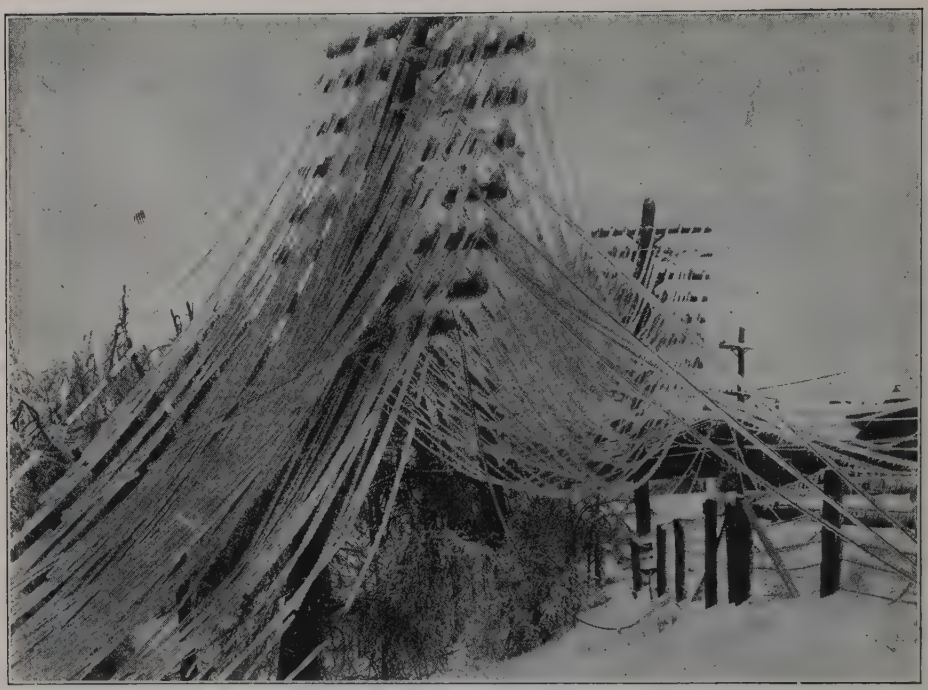
Every country has many things to brag about, but the central portion of the United States can surpass them all when it comes to tornadoes, blizzards and cold waves—things that add variety and give a greater zest, perhaps, to life in that delightful region. However, we must admit that the twister is really too interesting, in fact altogether mean; but on the other hand, the chance that a particular spot will be visited by a tornado during a given year is very small, less indeed than one in a thousand.

The tornado occurs most frequently in the spring of the year. The path of the average tornado is only 300 or

TORNADO CLOUD

This black, funnel-shaped, whirling cloud leaves destruction along its trail.

400 yards wide. Its length, however, may be anything up, in rare cases, to 100 miles, or even more. The whirling starts at the cloud level, and then burrows down through the air to the



UNDER THE RULE OF THE ICE KING
An ice storm at Worcester, Massachusetts, displaying the grip of rigorous weather.

ground, making a cloud as it goes that hangs down and twists about like the trunk of a fabulous elephant. Whatever this roaring vortex touches it treats with the utmost violence. Nothing that stands, tree nor house of any kind, is safe in its path—only a room underground is proof against its wrath. The danger in a tornado is very great, but the chance of being caught in one fortunately is very small.

THE COLD WAVE

When a gentle rain with light winds from the southeast is interrupted by cold blasts from the northwest, changing the rain as it falls to a coating of ice, or to rattling sleet, as occurs several times nearly every winter, we have the beginning of a cold wave, or, at least, the way a cold wave often begins. Instead of rain, there may have been at first a gentle snowstorm, interrupted in the same way by the cold blasts. In either case the clouds soon clear away and presently the wind dies down. Then for two or three mornings it gets colder and colder, until everything exposed is frozen tight. After this the weather slowly moderates, and the cold wave is gone.

THE BLIZZARD

The blizzard is another American specialty—name and all. No one knows exactly where the name came from, but the storm itself, a violent cold wind filled with blinding, driving snow comes out of the north. Its true home is the great plains beyond the Mississippi. Those who know it there in all its grandeur laugh when they hear an easterner call a mere snowstorm a

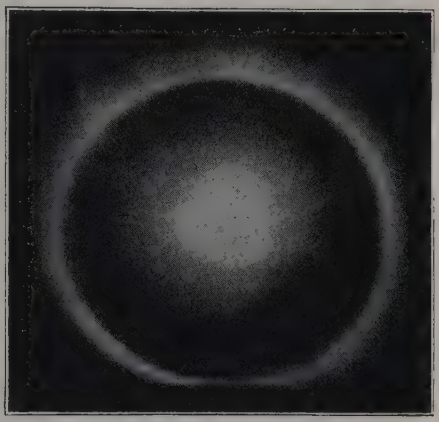
blizzard. It is nothing but a zephyr, they say, or at most, only a blizzet.

SKY SPLENDORS

Everything in the sky is interesting as soon as we begin to understand it, but some things are exquisitely beautiful, and always beautiful, no matter how much or how little we may know about them. The lightning flash, as it flies from cloud to cloud, or from cloud to earth, in winding and branching streaks of dazzling white, is one of the most beautiful and fascinating things of all nature.

A tamer beauty is the halo, a large ring around the moon or sun when covered with thin clouds. Frequently, but by no means always, this is a sign of coming rain or snow.

An almost equally beautiful display is the small ring or rings, the corona, often seen, especially about the moon, caused by the action of minute water drops on the light. This cloud-formed corona is entirely different from the solar corona, or shell and streamers of light about the sun, that make a total eclipse so interesting, but it often is just as pretty and always more regular in shape. When the drops are exceedingly small, portions of this ring may be seen at a considerable distance—not from the moon, for its light is too feeble, but from the sun. In this case we do not call the beautiful splotches of pearly pinks and opal greens a corona, but an iridescent cloud. This exquisite display of delicate colors is most frequently seen in high, thin clouds during the fall of the year.



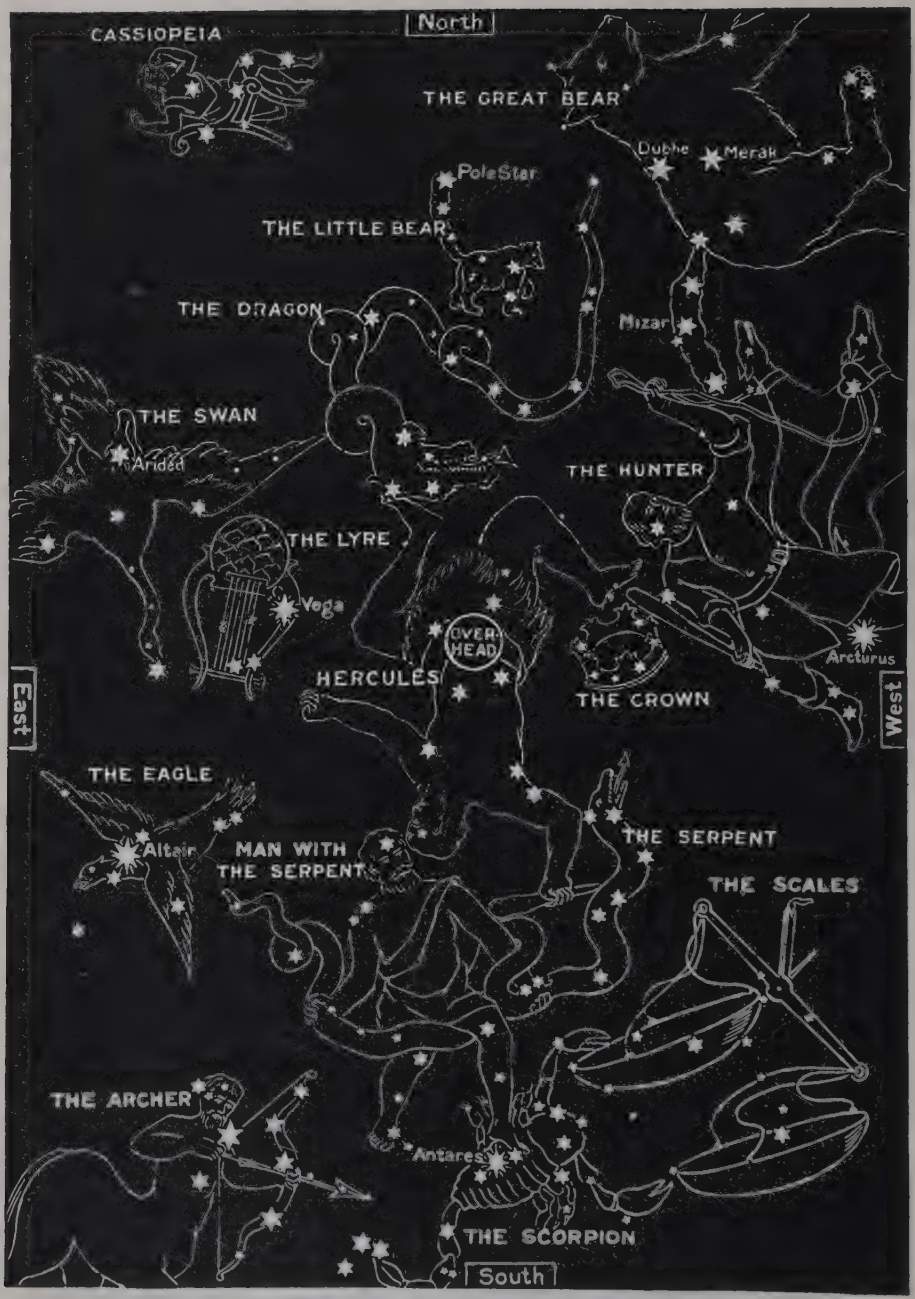
HALO OF THE SUN

The most common halo, or large circle about the sun or moon; red on the inside.

Finally, we have the rainbow, "the bridge of the gods," as it most appropriately has been called, caused by the shining of the sun on raindrops, which split the original white light up into many colors and sort them out, always in the same order, red on one side and blue on the other, with yellow and green between.

BROKEN ISLANDS OF CLOUDS

This photograph, taken in the mountains of North Carolina, shows cumulus clouds and also fracto-cumulus, or "broken" masses of the same formations.



PICTURE-MAP OF THE STARS IN SUMMER

Stand facing the south and hold the map above your head with the top of the map pointing north.

When we begin the study of the stars we soon learn that they are grouped into constellations (meaning "stars together"). Some of these constellations have curious names because the ancients named them after their gods, or animals, or after things which the stars were supposed to resemble.

THE PLEIADES—THE SEVEN SISTERS OF THE SKY

From the painting by Elihu Vedder in the Metropolitan Museum of Art, New York City. According to Greek legend these seven sisters, daughters of Atlas and Pleione, were transformed into stars. One sister, who married a mortal, hid herself from shame, and hence only six stars are seen in the Pleiades group.

THE CONSTELLATIONS

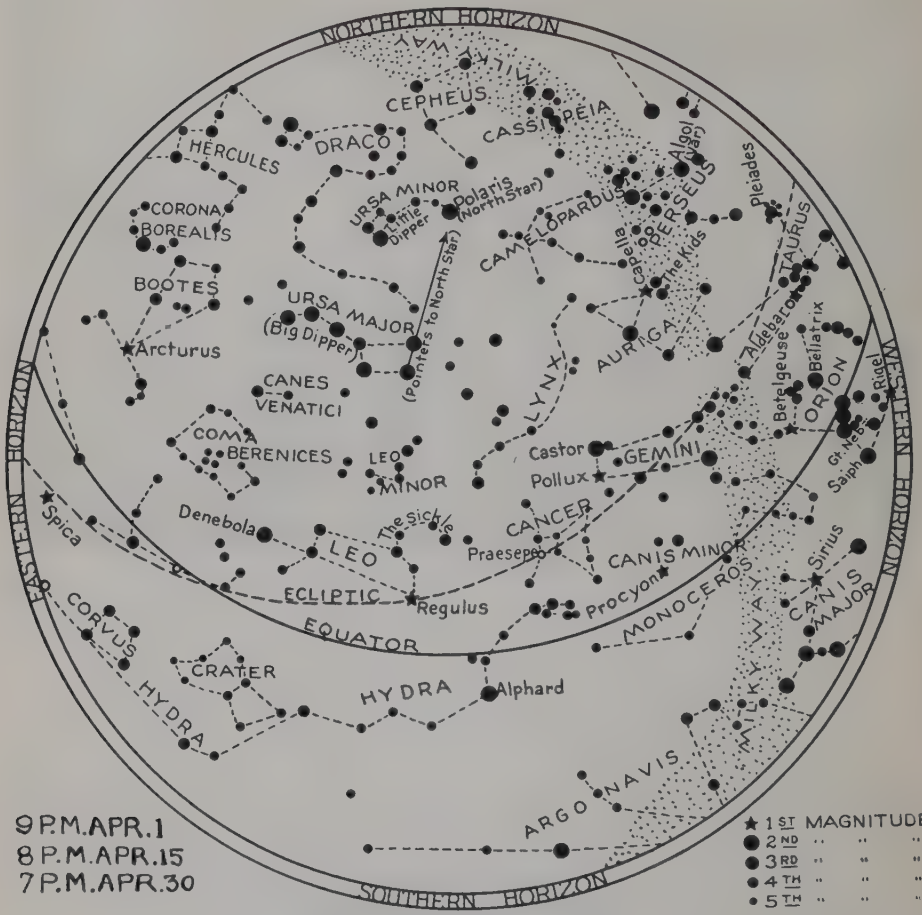
EVERYBODY should know something about the heavens, not only for the pleasure that acquaintance with the stars brings, but also because at some time this knowledge may prove to be of real value and service. Possibly you have heard how, during the World War, an American soldier who had been captured by the enemy made his escape, hiding by day and depending upon the stars alone to guide him by night.

To the navigator, the explorer and the surveyor, the stars are indispensable. Our clocks are set, boundaries laid on land, and ships sailed on the seas with the aid of the stars, and the time may come in the life of any one of us when a knowledge of the stars may prove invaluable when camping, walking, exploring, or possibly, flying.

The entire heavens are divided into groups of stars known as constellations. Many of these groups were named centuries ago, either for famous heroes of mythology, such as Hercules and Perseus; or for animals, as Leo, The Lion; Taurus, The Bull; Ursa Major and Ursa Minor, The Greater Bear and The Smaller Bear; or again for some familiar object, as Crux, The Cross; Lyra, The Lyre; Sagitta, The Arrow.

How Ptolemy of Egypt First Named Forty-Eight Constellations

There are today between eighty and ninety constellations known to astronomers, and, though the exact boundaries between some of the constellations are still unsettled, every star in the heavens may be said to belong to one or another of these groups. Forty-eight of the constella-



MAP* OF THE STARS IN SPRING

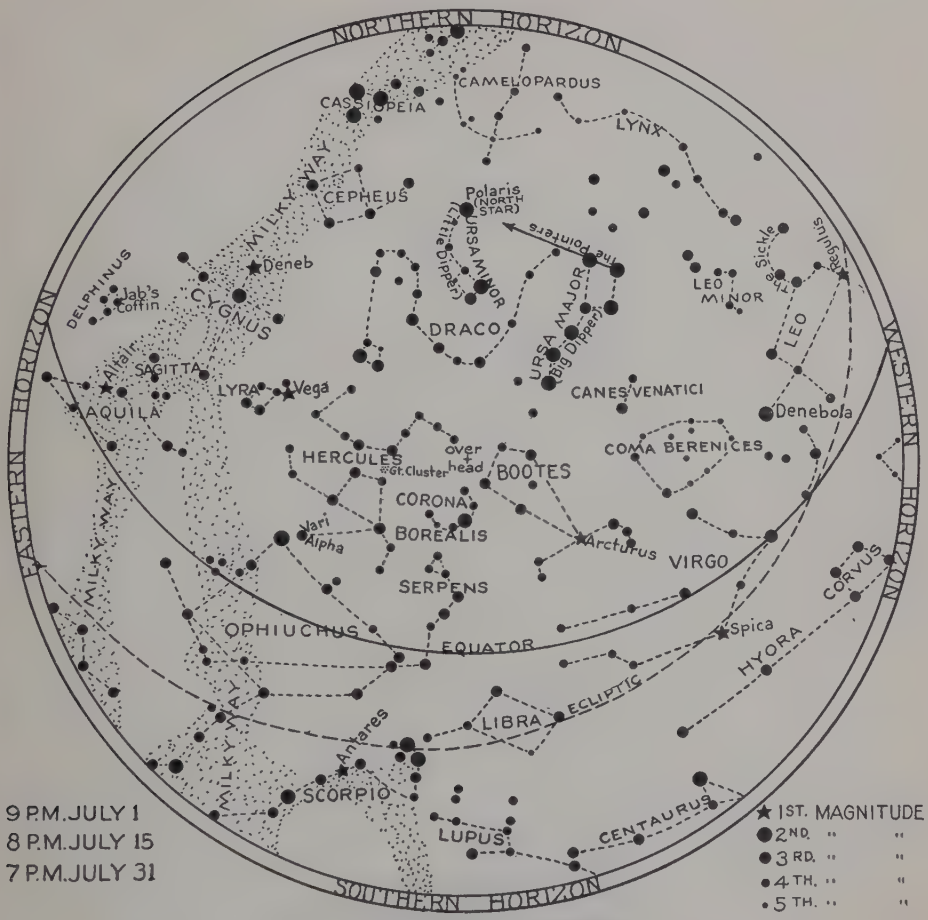
Hold the map directly overhead and at the times indicated at the left.

tions—"the ancient forty-eight," as they are called—were named and described by the famous astronomer Ptolemy, of Alexandria, Egypt, about 140 A. D. Ptolemy in preparing his list made use of the forty-nine constellations which were named several centuries earlier in the first star catalogue, made by the great Greek astronomer, Hipparchus.

THE FAMOUS ASTRONOMERS OF ARABIA AND CHALDEA

The Arabians and the Chaldeans also were great astronomers. Many of the names of constellations used by the Greeks originated in western Asia in the country bordering on the Euphrates River. Some of these earlier groups were known even in prehistoric days, it is believed. A number of the brightest stars still bear Arabic names, as Vega, Aldebaran, Deneb, Betelgeuse and Mizar. Most of the constellations of today have Latin names. Yet the Romans were poor astronomers, and got their knowledge of the stars mostly from the Greeks, merely giving the Latin names to constellations already in existence and adding few if any groups of their own.

*The star maps, Pages 52 to 55, are used by permission of *Nature Magazine*.



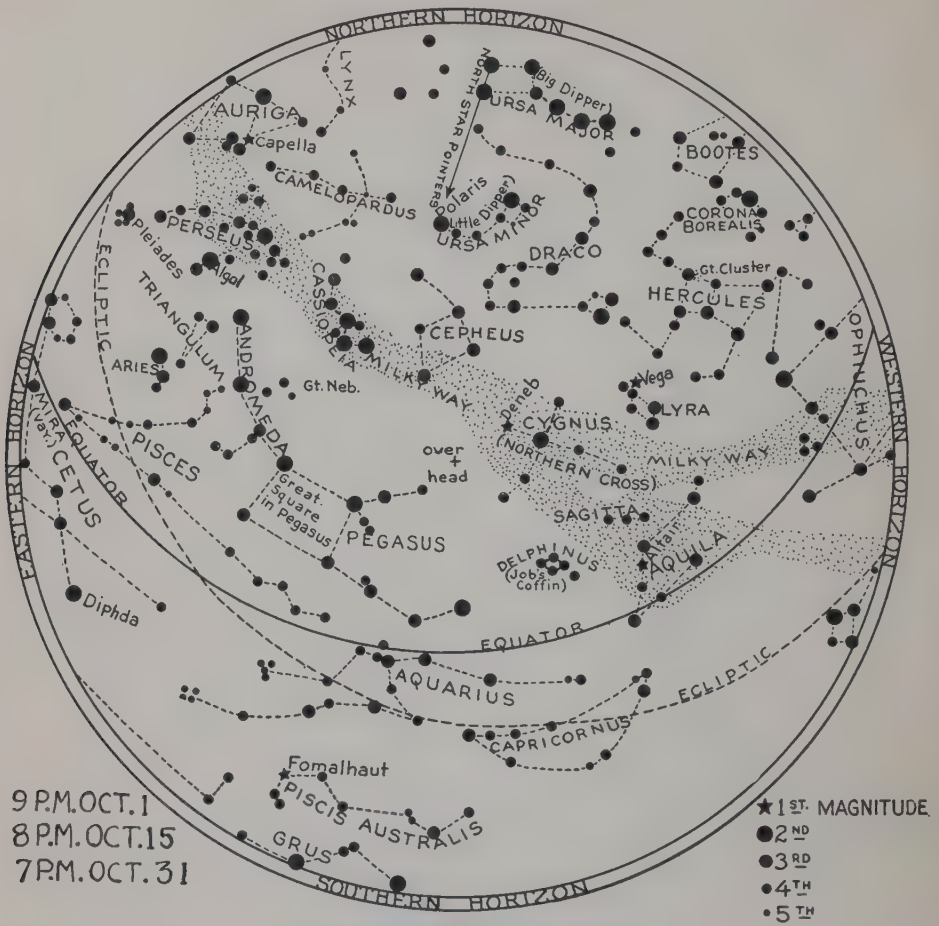
MAP OF THE STARS IN SUMMER

The ancient forty-eight constellations by no means covered all of the heavens or even that part visible from Greece, northern Africa or Arabia. So, from time to time, new constellations were added to fill the unnamed gaps in the heavens, particularly in the far southern heavens which were unknown to the northern astronomers until explorers of the southern hemisphere charted unknown stars as well as unknown lands.

Among ancient races the heavenly bodies were frequently objects of worship. Some races honored the sun above everything else, others the moon, or a star of exceptional brightness, as Sirius or Canopus. Temples were often built in such a way that the light of a certain star would fall through a long passageway upon an inner shrine on a certain date, usually at the beginning of spring or summer.

Astrology—the false astronomy

The false science of astrology, which attempts to show a connection between the affairs of men and the heavenly bodies, was universally believed in during the early ages. Throughout the Middle Ages and even up to a few centuries ago the astrologers had great



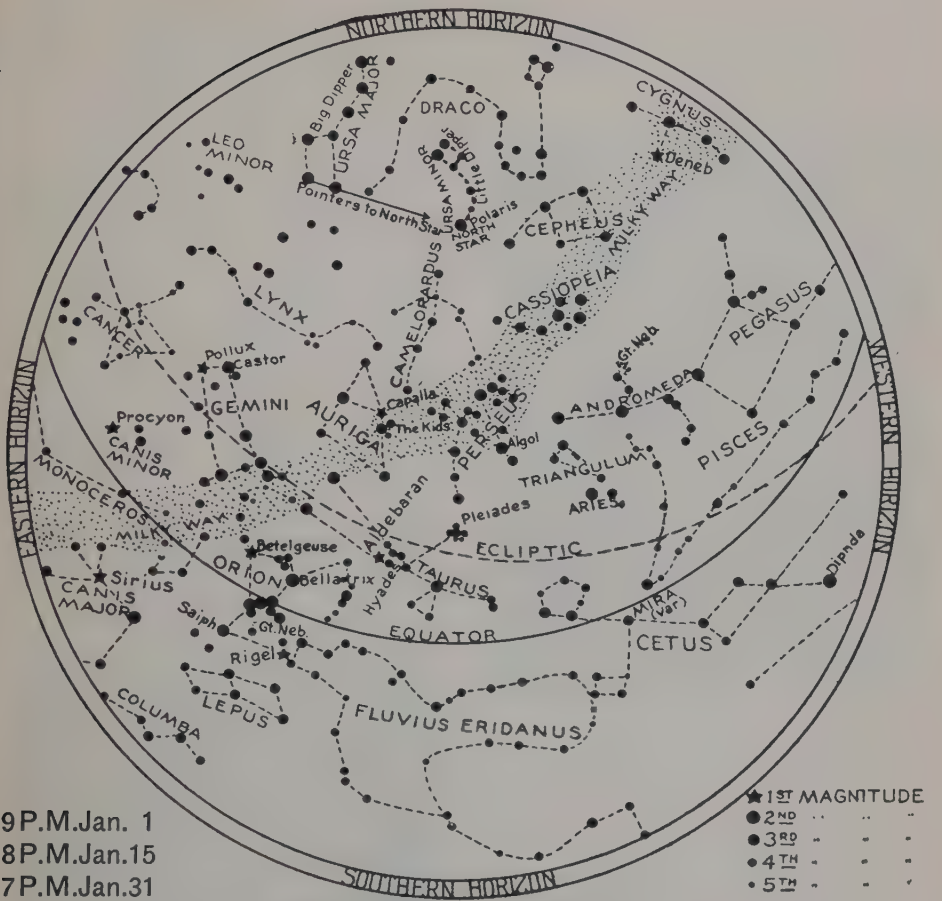
MAP OF THE STARS IN AUTUMN

influence over people and astronomy received scant attention while astrology flourished. The famous astronomer Kepler, who lived at the same time as Galileo, another very famous astronomer, about three centuries ago called astrology, "the foolish child of a wise mother."

As our knowledge of astronomy increases, we realize more and more the absurdity of believing that the stars or planets have any influence over our lives. Yet there are, even today, a few astrologers who have a small following among the superstitious, as have also the palmists and fortune-tellers.

THE "BELT OF THE ANIMALS"

Among the oldest constellations are the twelve that form the zodiac—a word that means, "Belt of Animals." The origin of the zodiac can be traced back to the earliest astronomy of the Euphrates country. It is believed that at first there were but six groups, or "Signs of the Zodiac," as they were called, namely: Taurus, Cancer, Virgo, Scorpio, Capricornus and Pisces. Later these were divided into eleven, and finally a twelfth, Libra, was formed from the stars that formerly represented the claws of Scorpio, The Scorpion. The names of the twelve con-



MAP OF THE STARS IN WINTER

stellations of the zodiac are: Aries, The Ram; Taurus, The Bull; Gemini, The Twins; Cancer, The Crab; Leo, The Lion; Virgo, The Virgin or Maiden; Libra, The Scales; Scorpio, The Scorpion; Sagittarius, The Archer; Capricornus, The Sea-goat; Aquarius, The Water-bearer and Pisces, The Fishes. As most of these constellations are named for animals and as they form a belt of the heavens lying along the ecliptic, which is the apparent path of the sun in the heavens, it is easy to see how the name "Belt of Animals" originated. The various figures that represent these twelve constellations of the zodiac often appear as decorations on the walls or floors of public buildings or libraries. If you ever visit the Library of Congress at Washington, you will find them inlaid in brass in the floor of the entrance pavilion.

The moon and planets never get far away from the ecliptic, or apparent path of the sun through the heavens, which is also the *true* path of the earth around the sun. They, as well as the sun, will, therefore, be found only among the constellations of the zodiac which lie also along the ecliptic. The moon makes a complete circuit of the zodiacal constellations every month,

the sun once a year, but the planets appear to wander among these constellations in what seems a strange manner until their motions with respect to the earth and the sun are understood. Then their apparent wanderings through the constellations of the zodiac are seen to be the result of their own motion around the sun and their change of position with respect to the earth which is also moving around the sun. Their motions are, then, very simple after all, when it is understood that they are moving around the sun and not around the earth, something that it took men centuries to find out.

ORION

Considered the finest of all the constellations. You may see Orion in the evening from November to May. In August, you will find this group of stars in the early morning, before sunrise.

The stars form a far distant background, against which we see the sun, moon and planets constantly changing their positions as we on our planet, Earth, make our yearly trips around the sun. The stars, we will find later, are also moving in various directions. They are not all equally distant from the earth, set, fixed and immovable in a celestial sphere revolving around the earth, as the ancients believed. The fact that they have appeared to keep the same positions in the heavens for so many centuries, so that the constellations of today are the same as they were thousands of years ago, is due to the fact that they are at such tremendously great distances from our solar system and the earth. Many centuries pass before the change in position of even the nearest of the stars, with respect to one another, can be noticed without the aid of a telescope.

SOME VERY IMPORTANT CONSTELLATIONS

The stargazer soon learns to look for different constellations at different hours of the night, as the earth faces all parts of the heaven in turn in spinning on its axis once every twenty-four hours. He will also find that different

THE DIPPERS

Ursa Minor, the Little Dipper and Ursa Major, the Big Dipper. Note how the two "Pointer" stars locate the North Star, which is at the end of the handle of the Little Dipper.

constellations appear at the same hour of the night in different seasons as the earth goes around the sun.

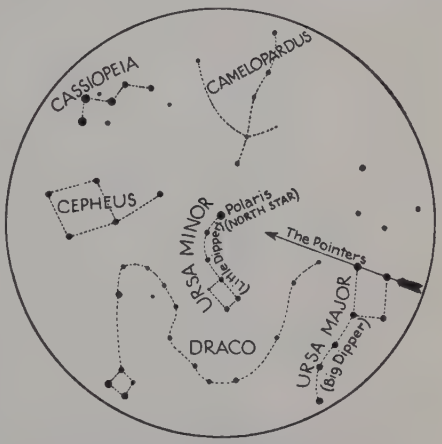
Orion, which is considered the finest of all the constellations, may be seen in the evening hours from November to May, but to see it in August one must look in the eastern sky in the early morning hours before sunrise. Hercules and Boötes, Virgo and Scorpio, we associate with summer evenings; Cygnus and Pegasus with fall; Leo with spring.

There are certain constellations that, we find, never pass below our horizon. These are the circumpolar (around-the-pole) constellations. In our northern latitudes they are the far northern constellations, surrounding the north pole of the heavens, which lies directly above the north pole of the earth.

THE TWO CROSSES

Though shown on the same map, these two crosses are far apart in the heavens. The upper, or Northern Cross, is in the constellation of Cygnus, the Swan. The lower or Southern Cross, is the famous "night clock" of the southern hemisphere.

They are, by name, Ursa Major and Ursa Minor, The Greater Bear and The Smaller Bear, in which appear the Big and Little Dipper, respectively; Draco, The Dragon; Cassiopeia—that W-shaped group which nearly everyone



NORTH CIRCUMPOLAR GROUP

The far northern constellations of the northern hemisphere that never pass below the horizon, north of 40° north latitude and are never seen above the horizon, south of 40° south latitude. Note the Dippers, the W of Cassiopeia, the faint Camelopardus, Cepheus and Draco, the Dragon with his tail between the two bears.

knows; Cepheus, and Camelopardus. At the end of the handle of the Little Dipper, or the tail of the Smaller Bear, is Polaris, The North Star.

In studying the constellations, one must learn to estimate in degrees the distances between stars. To say two stars appear to be a foot or a yard apart has no meaning. It is well to remember here, that the distance between "The Pointers" of the Big Dipper in Ursa Major is about five degrees; the distance from The Pointers to the North Star is about thirty degrees, and the extent of the Big Dipper is nearly thirty degrees. From the horizon to the zenith, or highest point overhead, is ninety degrees.

The elevation of the North Star above the horizon is always equal to the latitude of the observer. For example, in 40° North Latitude, the North Star is 40° above the northern horizon. At the north pole it is 90° above the horizon or directly over-

head. At the equator the North Star lies on the northern horizon. As you cross the equator traveling southward the North Star sinks from view below your northern horizon and the south pole of the heavens rises higher and higher as you continue your journey southward. Unfortunately, there is no bright star near the south pole to mark its position. The entire region surrounding the south pole of the heavens contains only faint stars. There are, however, many beautiful constellations of the southern hemisphere that come more and more into view as we pass southward through the tropics and enter the southern hemisphere. There is the wonderful Crux, The Southern Cross, the "night clock" of the southern hemisphere; and the glorious constellations of Argo Navis, named for the ship of the Argonauts; and the Magellanic Clouds of the southern circumpolar regions, named for the great explorer, Magellan, who saw them nearly over head as he passed through the Straits that bear his name.

THE TWENTY BRIGHTEST STARS IN THE HEAVENS

Everyone should know the twenty brightest stars in the heavens, and be able to recognize as many of them as are visible in our latitudes.

The following is a list of these brightest stars, in the order of their brightness, with the constellations in which they are found, their color, and the date on which they cross the meridian—the due north and south line—at nine o'clock in the evening:

Sirius	Canis Major	White	Feb. 12
Canopus	Argo Navis	White	Feb. 8
Alpha Centauri	Centaurus	Yellow	June 15
Vega	Lyra	Bluish-white	Aug. 15
Capella	Auriga	Yellow	Jan. 20
Arcturus	Boötes	Orange	June 10
Rigel	Orion	Bluish-white	Jan. 20
Procyon	Canis Minor	White	Feb. 26
Achernar	Eridanus	Bluish-white	Dec. 2
Beta Centauri	Arcturus	Bluish-white	June 7
Betelgeuse	Orion	Red	Jan. 31
Altair	Aquila	White	Sept. 4
Alpha Crucis	Crux	Bluish-white	May 14
Aldebaran	Taurus	Red	Jan. 11
Pollux	Gemini	Yellow	Feb. 28
Spica	Virgo	Bluish-white	May 29
Antares	Scorpio	Red	July 12
Fomalhaut	Piscis Australis	White	Oct. 24
Deneb	Cygnus	White	Sept. 19
Regulus	Leo	White	April 8

Of these Canopus, Alpha Centauri, Achernar, Beta Centauri and Alpha Crucis are not visible in 40° North Latitude.

A LIST OF THE PRINCIPAL CONSTELLATIONS

NAME OF CONSTELLATION	MEANING OF NAME	BRIGHTEST STAR
1. *Northern Circumpolar Constellations.* (These constellations never set north of 40° N. Lat. and never rise in or south of 40° S. Lat.)		
Cassiopeia		Schedir (variable)
Camelopardus	The Camelopard	*
Ursa Major	Greater Bear	Alioth
Ursa Minor	Lesser Bear	Polaris
Draco	The Dragon	Gamma Draconis
Cepheus		Alpha Cephei

*Blanks in last column indicate no conspicuous star of first or second magnitude.

Name of Constellation	Meaning of Name	Brightest Star
2. *Southern Circumpolar Constellations.* (These constellations never set south of 40° S. Lat. and never rise in or north of 40° N. Lat.)		
Tucana	The Toucan	.....
Pavo	The Peacock	Alpha Pavonis
Ara	The Altar	Beta Arae
Triangulum Australe	The Southern Triangle	Alpha Trianguli
Crux	The Cross	Alpha Crucis
Volans	The Flying Fish	Gamma Volantis
Mensa	The Table	.....
Dorado	The Goldfish	.....
Hydrus	The Serpent	Beta Hydri
Octans	The Octant	.....
3. *The Zodiacal Constellations.* (These constellations lie in the path of the ecliptic, the apparent yearly path of the sun among the stars. The moon and the planets as well as the sun will always be found among the Zodiacal groups.)		
Aries	The Ram	Alpha Arietis
Taurus	The Bull	Aldebaran
Gemini	The Twins	Pollux
Cancer	The Crab	.....
Leo	The Lion	Regulus
Virgo	The Maiden	Spica
Libra	The Scales	Beta Librae
Scorpio	The Scorpion	Antares
Sagittarius	The Archer	Epsilon Sagittarii
Capricornus	The Sea-goat	Delta Capricorni
Aquarius	The Water-bearer	Beta Aquarii
Pisces	The Fishes	.....
4. *The Equatorial Constellations.* (These constellations lie in the path of the celestial equator and pass directly overhead at the earth's equator or within the tropics.)		
Cetus	The Whale	Diphda
Orion	.....	Rigel
Monoceros	The Unicorn	.....
Canis Minor	Lesser Dog	Procyon
Hydra	The Water Snake	Alpha Hydrae
Virgo†	The Maiden	Spica
Serpens	The Serpent	.....
Ophiuchus	The Serpent-bearer	Alpha Ophiuchi
Aquila	The Eagle	Altair
Aquarius†	The Water-bearer	Beta Aquarii
Pisces†	The Fishes	.....

†A Zodiacal constellation also; equator and ecliptic intersect in Virgo and Pisces.

Name of Constellation	Meaning of Name	Brightest Star
5. Northern Constellations. (Constellations passing overhead in mid-latitudes of northern Hemisphere, but partly or wholly visible in mid-latitudes of southern Hemisphere.)		
Andromeda	.....	Alpheratz
Triangulum	The Triangle	.....
Perseus	.....	Alpha Persei
Auriga	The Charioteer	Capella
Lynx	The Lynx	.....
Leo Minor	Lesser Lion	.....
Canes Venatici	The Hunting Dogs	Cor Caroli
Coma Berenices	Berenice's Hair	.....
Boötes	The Herdsman	Arcturus
Corona Borealis	The Northern Crown	Alphacca
Hercules	.....	Beta Herculis
Lyra	The Lyre	Vega
Cygnus	The Swan	Arided or Deneb Cygni
Sagitta	The Arrow	.....
Delphinus	The Dolphin	.....
Pegasus	The Winged Horse	Scheat
6. Southern Constellations. (Constellations passing overhead in mid-latitudes of southern Hemisphere, but partly or wholly visible in mid-latitudes of northern Hemisphere.)		
Phoenix	.....	Alpha Phoenicis
Sculptor	The Sculptor	.....
Piscis Australis	Southern Fish	Fomalhaut
Grus	The Crane	Alpha Gruis
Indus	The Indian	.....
Telescopium	The Telescope	.....
Lupus	The Wolf	Theta Lupi
Centaurus	The Centaur	Alpha Centauri
Corvus‡	The Crow	Beta Corvi
Crater‡	The Cup	.....
Argo Navis	The Ship Argo	Canopus
1. Carina	The Keel	.....
2. Vela	The Sails	.....
3. Malus	The Mast	.....
4. Puppis	The Stern	.....
Canis Major	Greater Dog	Sirius
Columba	The Dove	.....
Lepus‡	The Hare	.....
Eridanus	The River Eridanus	Achernar

‡Passes overhead in latitude 20° South.

THE WILLAMETTE METEORITE

Sun, planets, moons, asteroids, comets, meteors—these constitute our solar system. This meteorite (meaning simply a large meteor), which now rests in the American Museum of Natural History, New York City, is from Willamette, Oregon.

THE SOLAR SYSTEM

THE sun, and all the bodies that circle around it, the nine planets (including the earth on which we live), the moons or satellites which revolve around some of them, the asteroids, the comets, and the meteors make up what is known as our solar system.

THE PLANETS

The most important of these bodies are the nine planets, named in the order of their distance outward from the sun — Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. The last three were discovered in modern times. Pluto, the latest discovery, was first seen on January 31, 1930, from the Lowell Observatory at Flagstaff, Arizona. Both Pluto and Neptune are very faint objects; neither can be found without a telescope. Uranus is just barely visible without the aid of a telescope and looks like a faint star.

The five nearest planets—Mercury, Venus, Mars, Jupiter and Saturn—look like very brilliant stars. Venus is far brighter than any star in the heavens or any other planet. Jupiter comes next in brightness, and no star except Sirius can rival it. On rare occasions, when exceptionally close to the earth, Mars becomes, for a short time, even brighter than Jupiter, and then again, when it is far from the earth, it is not as bright as the North Star. You see, the planets change continually in brightness as they approach or recede from the earth in their trips around the sun. Mercury, which is the nearest to the sun, as well as the smallest of all the planets, is never seen except in the twilight just before sunrise or after sunset, according to where it happens to be in its path. Many people have never seen this planet, or, if they have seen it, they have failed to recognize it; but it is a very easy matter to find Mercury at certain times, if you know just where and when to look for it. It looks like a very beautiful star of the first magnitude.

Saturn also looks like a brilliant star of the first magnitude, though, because of its greater distance from us, it is much less bright than Jupiter. There are but two stars—Sirius and Canopus—that surpass Saturn in brightness when it is seen at its best.

How the brightness of planets is different from the brightness of stars

We have been speaking of the brightness of the planets compared with that of the stars; but right here

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SUN AND NEARBY PLANETS

The planets Saturn, Uranus, Neptune and Pluto are too remote from the sun to be shown. The asteroids between Mars and Jupiter vary in size from one 485 miles in diameter to some probably no larger than an ordinary house.

we should make it clear that the planets shine in a very different way, and for a very different reason, than the stars.

The stars are fiery hot bodies, suns like our own, giving forth light and heat. Many of them possibly have planets of their own. They appear as points of light simply because they are at such tremendous distances from our solar system and the earth.

All of the planets, on the other hand, are cold, dark bodies that have no light or heat of their own; but they shine because they reflect the rays of the sun about which they revolve. They shine for the same reason that a stone glistens in the sunlight, as it throws back to us the rays of the sun that fall upon it. If you could look at our planet Earth from the surface of the planet Venus, it would appear like a brilliant and beautiful star, just as Venus does to us. The fainter star, close by it and revolving around it, would be our own satellite or attendant, the moon.

Why stars seem never to move

Then there are two other very important differences between stars and planets. The stars, you know, do not change their positions in the heavens with respect to one another for many centuries, because they are so far away that, though they are moving, we cannot detect this motion for ages and ages. You know how it is when a train rushes by you at full speed at a crossing; yet when you see it miles away, on a mountain grade, it seems to be crawling along, though its speed is unchanged. It is just the same with the stars. Great distance makes them appear immovable, though they, too, are rushing along at high speed. But the planets are very near, members of our own family in the heavens, all children of our sun, and so they appear to move among the stars from night to night, and therefore the ancients named them planets, which, in Greek, means "wanderers."

If you see a brilliant star in the heavens some night, and wonder whether it is a star or a planet, watch it for several weeks from night to night, and, if its position is changing with respect to stars nearby, it is a planet. Of course, the more distant planets, Jupiter and Saturn, will seem to move much more slowly among the stars than Venus or Mercury, which are quite near to the earth, and which change their positions very rapidly.

You will notice a change in position of Mercury and Venus among the stars in a few days; but several weeks may pass before you notice any change in the position of Saturn.

How the telescope shows the difference between stars and planets

Another difference between the stars and planets is that, in the telescope, the stars still remain points of light only, while the planets have a disk-like appearance like the sun and moon. Of course all of the planets are spheres like the earth, moon and sun and when you look at the moon, for instance, with a very powerful telescope, which makes it appear only a hundred miles or so away, the flat, disk-like appearance is gone, and you notice the curvature of the surface at which you are looking.

Some personal notes on our brother and sister planets

The four inner planets—Mercury, Venus, Earth and Mars—are small compared with the four large outer planets—Jupiter, Saturn, Uranus and Neptune—which are about ten times greater in size and ten times farther away from the sun than the small worlds first mentioned.

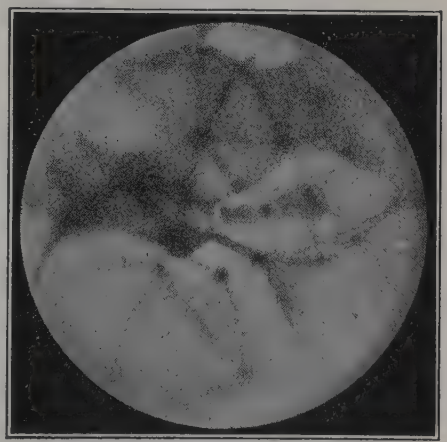
Mercury, the smallest of the planets, has no atmosphere; and its surface is barren and rocky like that of our moon.

Venus—the planet that keeps us guessing

Venus, on the other hand, which has been called "our sister planet," because it is nearly equal to the earth in size, has a dense atmosphere which hides its surface from our view, and reflects the rays of the sun with great brilliancy. We cannot tell what is taking place on the surface of Venus because we cannot see it, but some astronomers are inclined to believe that Venus is more likely to be an inhabited world than any of the planets other than Earth.

Do people live on Mars

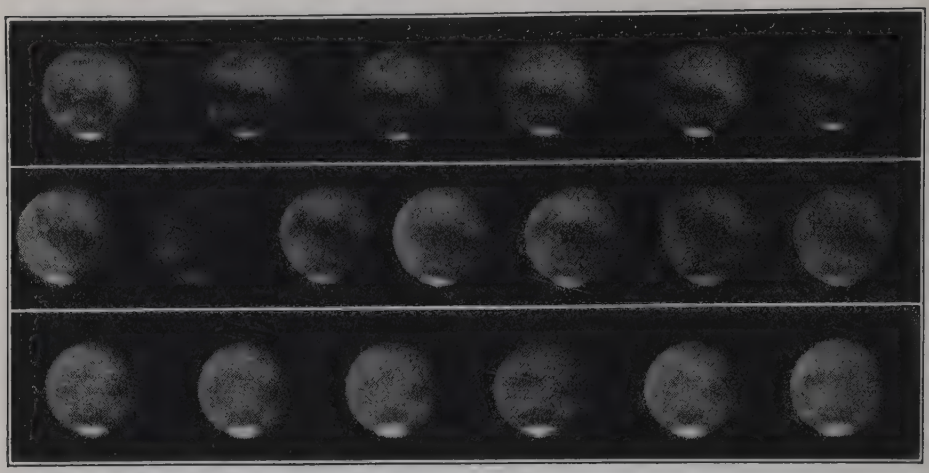
Mars is one of the most interesting of all the planets, because we can see a great many changes in the markings on its surface, which seem to show that there may be vegetable and animal life on this little neighboring world in the sky. Mars has a day about equal in length to our own day, and seasons very like the seasons on the earth; but they are twice as long as our seasons, for the year of Mars, which is its period of revolution around the sun, is about twice as long as our year.



MARS

This drawing by R. J. Trumpler of Lick Observatory is perhaps the best in existence showing the canals on the planet

There is, we know, air on Mars, though there is much less of it than there is on our own planet. There is also water, for clouds have been seen in the atmosphere of Mars. It is believed that Mars has frequent snowstorms too. It has caps of snow and ice over its poles, sometimes coming halfway down to the planet's equator in midwinter; and these snow caps melt, and often disappear entirely, as summer advances. The dark regions on the planet, which are believed to be vegetation, become greenish in color as the water from the melting snow



MARS

These photographs, made at Lowell Observatory, show three different faces of the planet. The photographs in the upper row were made August 2; middle row, August 12; and third row, August 16, 1924. The Martian seasonal dates are May 10, 16, 19, respectively. Note the decrease in size of the south polar snow caps.

caps quickens their growth. There are no signs of vast oceans or seas on Mars, such as are found on our planet; and the inhabitants of Mars, if there are such, cannot be extravagant with their water supply. There are vast, reddish tracts on Mars that are believed to be arid, sandy deserts, and sand storms on Mars must occur constantly.

Our small relatives—the asteroids

When we leave the planet Mars and pass outward in the direction of Jupiter, we come to the belt of the asteroids, or minor planets, which are numbered by the hundreds, and many of which are probably nothing more than huge meteoric rocks. The average size of the asteroids is about 50 miles in diameter, though there are four that are between 100 and 500 miles in diameter. A thousand or more of these asteroids have been discovered, named and catalogued. The smallest asteroids discovered are only about five miles in diameter. The astronomer finds it a difficult matter to keep track of all these tiny bodies and their paths, and sometimes they get lost and then are rediscovered later.

The outer planets

Except for Pluto, the outer planets —Jupiter, Saturn, Uranus and Neptune—are huge bodies compared with the Earth, Mercury, Venus and Mars, which are sometimes called the terrestrial planets, which means "similar to the earth." The terrestrial planets may be small, but they are very heavy for their size, being solid throughout. At least, this is known to be so in the case of the earth, which has a core of magnetic iron with an outer stony shell.

Unlike the terrestrial group, the outer planets are very light for their size, and are made up mostly of dense vapors and gases. Some believe that these planets are made up entirely of gases, greatly compressed toward the center like the sun, but it is also possible that they may have interiors of a pasty or molasses-like nature, surrounded by dense layers of gases. None of these planets has a solid surface crust, or could possibly be inhabited by forms of life such as exist on our own planet.

The most noticeable markings on the surfaces of the outer planets are

Courtesy Science and Invention

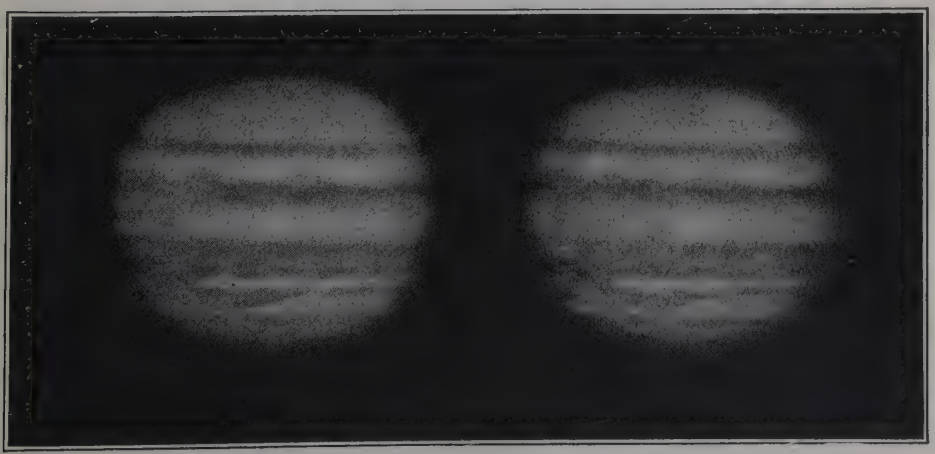
SOME PLANETS AND THE ASTEROIDS

Showing the comparative size of some of the planets—Earth, Mars and Mercury—and the total volume of all of the asteroids. Ceres, Pallas, Vesta and Juno are the largest of the asteroids. Ceres has a diameter of 485 miles; Juno, 118 miles.

belts of gaseous matter in their atmospheres, drawn parallel to the equators of the planets by their rapid whirling on their axes. Though those planets are far greater in size than the earth, they spin around on their axes in less than half the time. These belts are most noticeable in the planet Jupiter, which is the nearest to us of these four planets. Jupiter is one of the most interesting of all the planets of the solar system to observe through the telescope, not only because of its ever-changing surface markings but because of the interesting behavior of four of its satellites. These were discovered by Galileo with his first telescope and are easily seen in the smallest telescopes, revolving around the huge planet, at one time disappearing in its shadow, at another showing as black dots against its surface, as they pass between us and the planet.

SATURN AND ITS MERRY-GO-ROUND—THE PLANET WHICH MIGHT FLOAT ON AN OCEAN

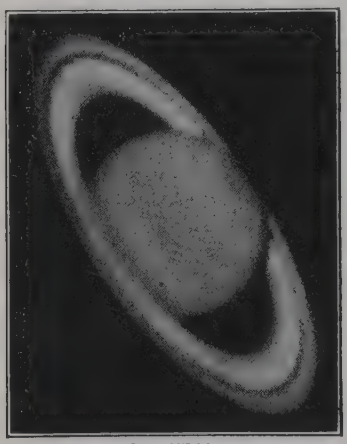
Saturn is a strange and unique planet for two reasons. It is so light that it would float in water as easily as a cork if we could find an ocean large enough to hold it; and it has, in addition, three rings, which are unlike anything else in the solar system. There is an inner dark ring about 11,000 miles wide, a principal bright ring 18,000 miles wide, and an outer ring, less bright than the principal ring, and also 11,000 miles wide. This



JUPITER

Photographed with the 24-inch refracting telescope at Lowell Observatory

ring is separated from the middle ring by a narrow gap, 2,200 miles wide, known as Cassim's Division, from its discoverer. The width of these rings altogether is over 40,000 miles, a little more than half the diameter of the planet itself. Our Earth, with its diameter of only 8,000 miles, could



SATURN

Photographed with the 24-inch refracting telescope at Lowell Observatory.

roll along the surface of the rings like a large ball on a road, while our moon would just fit into the gap between the Bright Ring and the Outer Ring. The thickness of the rings is only about 100 miles, which is no thicker in proportion to their great width than the thickness of a piece of paper. These rings of Saturn are made up of countless tiny moons, not much more than rocks in size at the most, possibly not more than grains of sand. Their exact size is unknown, but it is certain that it cannot be great. Each of these little moons is following its own independent path around Saturn. They form a sort of perpetual merry-go-round about the planet, the only one of its kind in the heavens.

Life is impossible on Pluto

Pluto, like the inner planets, is small and dense, its density exceeding that of the heaviest earthly surface rocks. Because of Pluto's long year, 250 earthly years, and its great distance from the sun, life is impossible on that planet.

The satellites of the planets

Mercury, Venus, and probably Pluto have no moons, or satellites, that revolve around them as planets revolve around the sun. Earth has one moon. Mars has two tiny moons, Phobos and Deimos. Nine moons surround Jupiter and nine or ten revolve around Saturn. Uranus has four moons and Neptune one.

Sky rockets of the heavens—the comets

The most spectacular-looking objects in the solar system are the comets, which are sometimes bodies of enormous size, though they contain very little substance. Our earth would suffer very little if any damage, if it encountered a comet "head-on." The head of a comet has a bright nucleus, which is probably made up of a cluster of small, stone-like masses, surrounded by gases and vapors. Usually a comet has a tail that is, in some cases, millions of miles long. The tail of a comet is composed of gases and vapors and minute particles, that are driven forth from the head of the comet by the pressure of light or radiations from the sun. For this reason the tail of the comet is always turned away from the sun.

Some comets are periodic and make return visits to the sun every few years, or after hundreds, or even thousands, of years have passed by. The orbit, or path, of a comet around the sun is very different from that of the planets, which travel in nearly circular orbits or ellipses, which look like circles that have been slightly flattened. Comets travel in orbits that are greatly elongated ellipses, or parabolas, or hyperbolas. If the comet is traveling around the sun in a parabola,

PATH OF COMET AROUND THE SUN

At one time this comet, which is travelling in an ellipse, comes close to the sun; then passing around the sun, it travels far beyond the planets, millions of miles into space, until it returns to the sun. The drawing shows also how the earth goes around the sun. A comet traveling in a parabola or in a hyperbola never returns to the sun. The size of the earth is greatly exaggerated in this diagram.

or hyperbola, it makes only one trip to the sun, and then disappears into outer space beyond the solar system, never to return. If it is traveling in an ellipse it will come again; how soon depends on the size of the ellipse. Many small comets have orbits that do not extend beyond the orbit of Jupiter, and so they return frequently and the astronomers can predict in advance when they will return to the neighborhood of the sun. These comets are usually faint, uninteresting objects, many of them tailless, and visible only in the telescopes.

The interesting comets are the ones that appear unexpectedly, and shine with great splendor for several weeks or so, and then rush away toward the outer limits of the solar system, slowing down in speed and losing their splendid tails as they get far away from the sun. Astronomers are not often caught napping, though, and often these new comets are discovered with the telescope when they are still many million miles beyond the earth's orbit. They then appear as small fuzzy patches of light. As they draw in toward the earth and sun they increase in size and brightness and usually develop tails under the action of the sun's rays.

Comets that continually return to the sun finally go to pieces under the action of the sun, and their remains are scattered along their paths in the form of swarms of meteors, which are dust-like particles of matter, formerly parts of the heads or tails of comets.

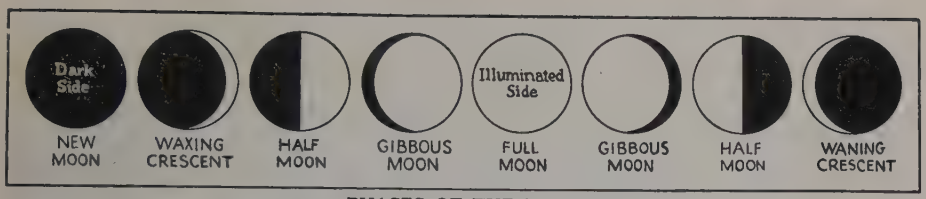
THE SHOOTING STARS THAT FOLLOW THE COMETS

There are many swarms of meteors going around the sun in the paths of former comets, and every year at certain times our planet, Earth, runs into some of these meteoric swarms when the orbit of the earth crosses that of the meteors. Then we have a display of meteors, or shooting stars, as these small dark particles enter the earth's atmosphere and flash up momentarily as a result of friction with the air which heats them to glowing incandescence. There are countless numbers of these meteoric particles throughout the solar system, and every day, in fact, the earth encounters meteoric particles that are captured and burnt up by its atmosphere. It has been calculated that millions of these dust-like particles enter the earth's atmosphere every day, but most of them are too faint to be seen. Meteors are often seen flitting across the field of view of the telescope.

A STORY THAT THE TELESCOPE TOLD

This comet is just like any ordinary one except that it has a forked tail. The telescope clock was set to follow the motion of the comet and the exposure was a long one. Therefore we see "star tracks" which look like little dashes in our picture.

Meteorites or fireballs is a name for meteors of great size that occasionally enter the earth's atmosphere, and, by friction with the air, become so heated that they seem to shine as brilliantly as bright stars or planets, and then, after exploding with a report like a cannon or a clap of thunder, fall to the earth. Many of these meteorites have been recovered, and will be found in our museums, visitors to the earth from space beyond. Most meteorites are composed of nearly pure iron, but some are stony compounds and other mixtures of iron and igneous, or heat-formed, rocks. The largest known meteoric mass weighed 73,000 pounds and was brought back from Cape York, Greenland, by Peary. The second largest lies in a plain near Bacubirito, in Mexico, and weighs about 50,000 pounds. The third largest is the meteorite which was found in a forest near Willamette, Oregon. These are all iron meteorites. The largest known stony meteorite, weighing about 650 pounds, fell at Knyahinya, Hungary, in 1866, in company with over a thousand other stones, which weighed altogether 1,000 pounds.



PHASES OF THE MOON

From new moon to new moon through one revolution of the moon around the earth. (For complete explanation of the causes, see Pages 70 to 72.)

THE MOON

THOUGH the moon is a very small world, it is, next to the sun, the most interesting and important to us of all the heavenly bodies, because it is the nearest to us, and at the same time our satellite, or attendant. It is the only one of all the worlds in space that goes around the earth as a center.

While the earth makes one yearly trip around the sun, the moon completes thirteen trips around the earth, and starts on a fourteenth, taking nearly twenty-seven and one-third days for each journey, counting from the time it is in line with some star until it returns to the same star again.

THE SIDE OF THE MOON THAT WE NEVER SEE

The moon goes around the earth in what may seem to be a very peculiar way. It always keeps the same face turned toward the earth so that there is one side of the moon that can never be seen from the earth. To keep the same face always turned toward us the moon has to turn just once on its axis while it is making one trip around the earth. The moon does not change the speed with which it turns on its axis; but it does change the speed with which it travels around the earth. When it is nearest the earth in its orbit it moves fastest, and when it is farthest from the earth it moves slowest, and so sometimes it gets ahead of the position it would be in if it were moving at a regular rate, and sometimes it falls behind that position. The result is that sometimes we can see a little around the eastern edge of the moon, and sometimes around the western edge. Then, too, the moon's axis is tilted to its orbit a little, so that sometimes we see a little beyond the north pole of the moon and sometimes a little beyond the south pole. So it is that we get a chance to see somewhat more than half of the moon's surface, peeking first around one edge and then around another. It has been found that there is only forty-one per cent instead of one-half of the moon's surface that we can never see—forty-one per cent that we always see, and eighteen per cent around the edges separating these two regions, that is sometimes visible and sometimes invisible.

HOW BIG AND HOW HEAVY IS THE MOON

The moon is so small, compared to the earth, that forty-nine globes the size of the moon could be made from our earth globe and four moons could be placed side by side along a diameter of the earth, overlapping only a little at the ends, since the diameter of the moon is a little more than one-fourth the diameter of the earth. The entire surface area of the moon is between one-thirteenth and one-fourteenth that of the earth. It would cover about as much surface on our planet as North and South America combined, while the visible surface of the moon, the

surface that is always turned toward the earth, is only about as large as the United States and Canada combined.

The material of which our earth is made is much more closely packed together than is the material of which the moon is made. If it were possible to put the earth in one pan of a pair of scales and the moon in the other pan, we would find that the earth would weigh about eighty-one times as much as the moon. That is, it would take eighty-one moons in one pan to balance the earth in the other pan.

What you would weigh on the moon

A boy who weighs seventy-two pounds on the earth would weigh only one-sixth as much, or twelve pounds on the moon. He would be able to jump or to throw a baseball six times as far as he can here on the earth. This is because at the surface of the moon the force of gravity, which holds any object to its surface, is only one-sixth as great as it is at the surface of the earth. If there should be a volcanic eruption on the moon, the matter thrown out from the crater of the volcano would be hurled six times as far as it would be on the earth.

How far away is the moon

The distance of the moon from the earth, on the average, is only 239,000 miles. As the moon's orbit is an ellipse, instead of a circle, its distance from the earth varies, and at times the moon may be as much as 15,000 miles nearer than this, and again 15,000 miles farther away. At its average distance, thirty globes the size of the earth placed in a row, side by side, would just about reach from the center of the earth to the center of the moon.

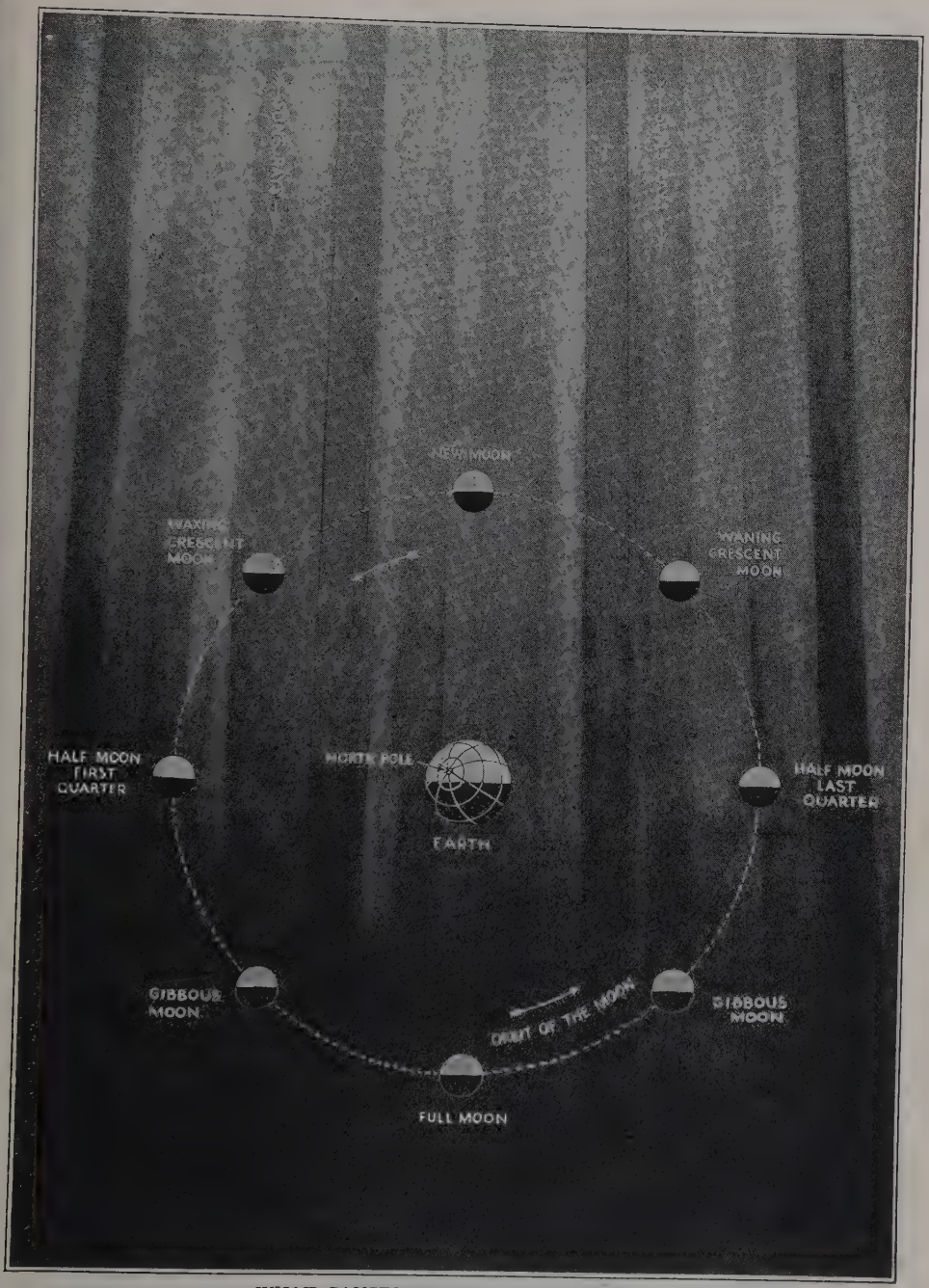
Day and night on the moon are each nearly fifteen days long

It takes the moon twenty-nine and one-half days to make a complete revolution around the earth *with respect to the sun*—that is, from new moon to new moon—and this is the length of the moon, or lunar, day and night combined. For half of this period, or nearly fifteen of our days, the sun is above the horizon and it is day on the moon, the sun apparently rising in the east, as it does here, crossing the meridian in the middle of the lunar day and setting in the west about fifteen days later. Then follows an equal period of darkness—the lunar night—when for nearly fifteen days the sun is never seen.

Cause of phases or change in appearance of the moon

Everyone knows of the phases of the moon—the different appearances of the moon at different parts of its orbit—crescent, gibbous (humped), full, but it is strange how very few people seem to understand the cause of these phases. At new moon—when we cannot see the moon at all except at the time of a total solar eclipse, because it is in line with the sun—all of the side of the moon turned toward us is in the darkness of night. The light, or day side, is then turned toward the sun. A day or two later we see a thin crescent moon in the west after sunset. The crescent is a small part of the day side that we can now see shining brilliantly by reflected light from the sun, as the moon gets a little to one side of the sun. Often, at this time, we also see the dark or night side of the moon faintly illuminated. This is called the "old moon in the new moon's arms." The faint light that we then see on the dark side of the moon is "earth-shine" on the moon, that is, sunlight reflected from our earth to the moon. We are, in fact, looking at the night side of the moon bathed in the light of the earth.

Viewed from the moon, the earth shows phases like those of the moon



WHAT CAUSES PHASES OF THE MOON

This diagram shows how the moon at different points in its orbit is illuminated by the sun. The ever-changing position of the illuminated side with respect to an observer on the earth produces the different phases corresponding to the different positions of the moon in its orbit.

This diagram shows the different positions of the moon in its orbit at the time of each phase. It does *not* show the phases themselves. These appear in the sketch on Page 69. You must remember that the moon is a sphere or globe and not a circle as shown here.

but just the opposite of what they are on the moon at any one time. When the moon is new to us, for example, the earth is full, viewed from the moon, and sends a flood of earth-shine, which is, in its nature, like our moonlight, to the moon.

As the moon gets farther along in its orbit to the east of the sun, we see more and more of its day side. It still appears like a crescent from the position in which we observe it, but the crescent is increasing in width each day. The sun is now rising more and more on the part of the surface that was in darkness a few days before, and as the crescent increases in size the dark part decreases. Soon half of the surface that is turned toward us is in darkness and half in sunlight, and we have the phase of "half-moon," which occurs a week after new moon, or at the first quarter of the moon's revolution in its orbit. After that the moon becomes "gibbous," and we see more of the day side than we do of the night side of the moon. The dark side is now getting less and less in area, as the sunlight creeps on over the side turned toward us, and next we have "full moon," two weeks after new moon. All of the day side of the moon is now turned toward us and fully lighted by the sun's rays.

The phases in reverse order

After the moon has been full, all of the phases from new to full moon come again in reverse order as the moon continues in its orbit around the earth; first, the gibbous phase, then the half moon, then the crescent, which grows thinner each day, until the last we see of the moon before it completes its journey around the earth from new moon to new moon is a thin crescent in the eastern sky just before sunrise. Soon it is new moon and all of the side turned toward the earth is again in darkness.

How early astronomers named surface features of the moon

When Galileo studied the surface of the moon with his first crude telescope, he thought that the dark, smooth areas that covered much of the moon's surface were large bodies of water. He called them Maria (Mä-ri-ä), which is Latin for seas, and gave them fanciful names, such as Sea of Tranquillity, Sea of Clouds, Sea of Conflicts. Smaller dark regions he and other early astronomers thought were marshes, lakes or bays, and they were given such names as Marsh of Corruption, Bay of Rainbows, Lake of Dreams. The Latin names, instead of the English translations that we have given here, were used. Lofty mountain ranges, ten of them in all, were also visible on the moon, even in the first imperfect telescopes, and most of them were named for earth's mountain ranges, as the Apennines, the Alps, the Caucasus. Two of them, near the south pole of the moon, the loftiest of all, were named for astronomers, and are known as the Leibnitz and the Doefel Mountains. The heights of the mountains were soon found accurately by measuring the length of the shadows they cast. The highest peaks of the Leibnitz and Doefel ranges are from 25,000 to 30,000 feet high, as high as some of the loftiest mountains on earth. If our earth mountains were as high in proportion to the size of the earth as the lunar mountains are in proportion to the size of the moon, they would have to average fifteen miles in height.

The craters of the moon

A most remarkable feature of the moon landscape, seen in the smallest telescopes and even in a small opera glass, are the deep pits and saucer-like holes with which the entire visible surface of the moon is riddled. There is nothing on our own planet that can be compared with these craters. Our vol-

THE MOON AT CLOSE RANGE

The most striking features of the moon landscape are the deep pits and saucer-like holes which are clearly shown in this interesting photograph. There is nothing on earth to compare with them in size, some being from sixty to more than a hundred miles in diameter. The moon's surface also shows long cracks, or rills, lofty mountains and vast plains.

canic craters are small affairs, usually only a few hundred feet across, and they are at the top of volcanic mountains. The very smallest of the lunar craters are several miles across, while the largest are from sixty to over a hundred miles in diameter. All of them are below the level of the surface, and often there is a central mountain peak, or cluster of peaks, rising from the floor of the crater, and a lofty rim, sometimes terraced, surrounds it. Sometimes fresh craters have formed on the edges or floors of old ones. Many are so large that anyone standing in the center could not see the surrounding walls, or edge, of the crater, because of the curvature of the moon's surface. Thirty thousand of the largest ones have been mapped and named, and there are many more thousand small ones, not much more than pits or holes in the surface, that are nameless. The early astronomers gave the names of Greek philosophers and ancient and medieval astronomers to most of the craters of the moon. The astronomer Riccioli seems to have started this method of naming in 1650, and later astronomers continued it. Plato, Copernicus, Eratosthenes, Ptolemy, Tycho are the names of some of the most noted craters.

Surface of moon better mapped than parts of earth's surface

So carefully have the astronomers mapped and studied the visible surface of the moon that it is better known than some of the unexplored regions of our own planet in Africa, Asia or the polar regions. Our position with respect to the moon gives us a great advantage in mapping its surface, just as photographs taken from airplanes give us excellent maps of the earth's surface. Our greatest telescopes, it should be remembered, bring the moon very close to us, and the absence of an atmosphere on the moon is a great aid in studying its surface.

Important features

Next to the craters the most important markings on the moon are the long cracks, or rills, like deep, narrow ravines, in its surface, and the streaks, or rays, that surround some of the most prominent craters, principally Tycho and Copernicus. The rays starting in Tycho extend for hundreds of miles across the surface of the moon, going out in all directions like spokes from a wheel. Their origin is a mystery. Some think that they are molten matter from the interior that has filled up cracks, or fissures, in the surface. Others think they may be splashings from some enormous meteoric body that struck a terrific blow on the surface of the moon.

Different explanations of how the moon and its craters were made

Some astronomers believe the craters were originally caused by collisions between the moon and meteoric masses of exceptional size in the early ages, when our solar system was being formed from a system of planetesimal or meteoric-like bodies. Others think that they are the result of tremendous volcanic eruptions on a far greater scale than anything of its kind that has ever occurred on our planet. There are also those who believe that the moon was, at some time in the distant past, a part of the earth, and that the moon was finally thrown off as a separate world.

It is still impossible to say which one of these theories of the origin of the moon or of its craters is the correct one. Much can be said for and against each one of them. The origin still remains unexplained, though it may be said that most astronomers believe in the theory of the volcanic origin of the craters.

No air, water, vegetation or life on the moon

Galileo and the early astronomers who first studied and named the features of the moon with the aid of telescopes thought the dark, smooth regions were seas. Better and more powerful telescopes soon showed that the dark regions were quite rough in places, and pitted with small craters, and could not possibly be water surfaces. It was found that no clouds ever appeared on the moon, and no color changes, such as would be produced by growth or decay of vegetation. The absence of air on the moon was shown in many ways. The lunar shadows are harsh and black, as one would expect them to be if there were no air. The surface shows no sign of weathering under the action of air and water. All is rugged and barren, apparently a lifeless waste. There are those who believe that some forms of life may exist in the cracks and crevices of the moon where there may be low-lying gases or vapors.

With no atmosphere to act as a blanket for the lunar surface and temper the extremes of heat and cold, the surface rocks of the moon must get heated to an enormously high temperature during the long lunar day. It has been estimated to be as high as the boiling point of water, 212° F., while during the equally long lunar night the temperature must drop to about the absolute zero of space, or -459° F.

Queer forms on surface of moon caused by light and dark areas

The face of the smiling, but homely, "Man in the Moon," and the beautiful profile of the "Lady in the Moon," are well known to almost everyone. When we turn to the telescope, though, we find that their features are formed by light and dark surface areas, which do not reflect the light of the sun with equal brightness.

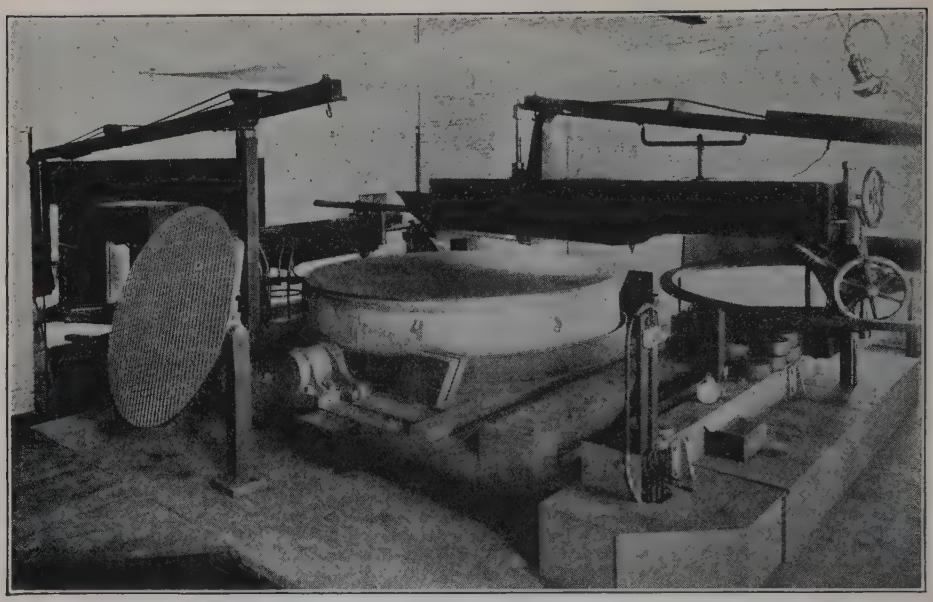
Because the markings on the surface do not change or move, the faces of the man in the moon and the lady in the moon never grow old.

WHAT IS WRONG?

The story of the moon makes it clear that we never could see a star within the crescent of the moon.

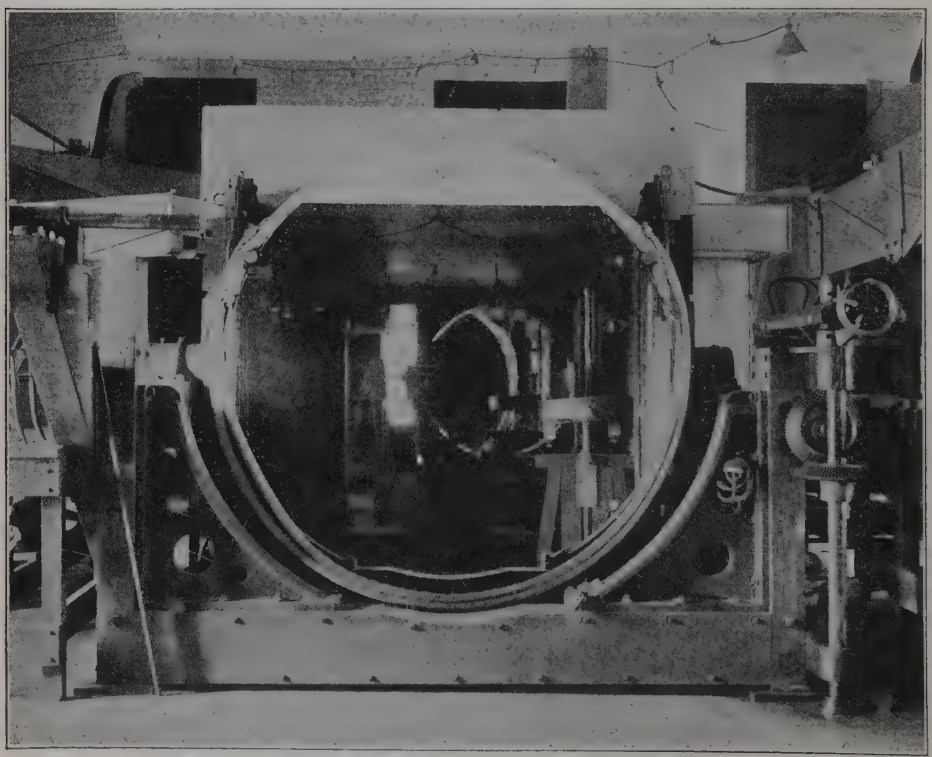
Best time to view the moon

The best time to look at the moon is not, as so many believe, when it is "full," but a few days after the first quarter. Then nearly all of the most interesting craters, mountains, and "seas" are plainly visible, and lighted in a slanting direction by the sun's rays. At the time of full moon there are no shadows on the moon, and many of the most interesting markings on the surface are entirely lost to view because there is no contrast between them and the surrounding surface. The only markings that can be seen to better advantage at full moon are the streaks radiating from some of the craters, particularly the crater Tycho, near the south pole of the moon, which then becomes the most striking feature of the landscape of the moon.



GRINDING THE LENS FOR A GREAT TELESCOPE

The wonderful 100-inch mirror for the Hooker Telescope on Mount Wilson. It is on the grinding machine, ready to be made concave. It is over a foot thick and weighs 9,000 pounds.



TESTING THE TELESCOPE LENS

Here we see the finished mirror, silvered and tipped forward into the testing position. The reflection shows the photographer's camera, a testing stand for the cassegrain mirrors and the five-foot optical flat that was used in testing the great 100-inch mirror.

TOTAL ECLIPSE OF THE SUN

This photograph of the total eclipse of the sun, January 24, 1925, was made by R. W. Bristol, Van Vleck Observatory, Wesleyan University, Middletown, Connecticut.

ECLIPSES

IN OLDEN times the cause of eclipses of the sun and moon was not so generally understood as it is today, and many tales have come down to us of the fear with which eclipses were observed.

Even up to the present time, in some parts of China, when there is an eclipse of the sun or moon, drums and tom-toms are beaten and cannons fired to scare away the dragon that the ignorant and superstitious believe is on the point of seizing the sun in his black claws.

In the history of Greece it is recorded that, in the midst of a battle between the Medes and the Persians in the year 585 B. C., there suddenly occurred a total eclipse of the sun, which it seems had been predicted in advance by the astronomer Thales. The sudden darkening of the face of the sun so terrified the warriors that they at once stopped fighting and made a lasting treaty of peace.

What does the Chaldean Saros mean

The ancient Chaldeans and Babylonians kept very complete records of eclipses, and these past records have been very valuable in fixing the dates of certain doubtful events in history.

The Chaldeans discovered that any eclipse would be followed, after eighteen years and eleven and one-third days had passed, by another eclipse that would be very similar to the first one. This is because of the fact that, after this period of time, sun, moon and earth return to the same positions in the heavens, and all of the conditions necessary for the occurrence of such an eclipse are repeated. This repetition of eclipses every eighteen years, eleven and one-third days, was called the Chaldean Saros—the word *Saros* meaning "repetition." Even today the Saros is sometimes made use of in roughly predicting the dates of future eclipses.

How eclipses of the sun occur

Eclipses of the sun can occur only at the time of new moon, when the moon passes between sun and earth. The moon shuts off the light of the sun, completely or partly, and throws its own shadow upon the earth's surface. The turning of the earth on its axis during the time that the moon is pass-

ing between sun and earth, as well as the eastward motion of the moon in its orbit, causes the shadow of the moon to move across the surface of the earth from west to east during the period of the eclipse. Some eclipses are partial and some are total. If total, the face of the sun is completely hidden by the moon for a short time within a narrow belt of the earth's surface about 5,000 miles long and 165 miles, or less, in width. This is the path that the moon's cone of shadow sweeps over as it intersects the earth's surface. If one is outside of this path he will still see the sun partly eclipsed within a certain distance on either side of the path of total eclipse. This larger area of the earth's surface, within which the sun's face is seen partly covered by the moon, is within the penumbral (partial shadow) shadow-cone, and the narrow path of total eclipse is within the umbral (full shadow) shadow-cone.

What are annular eclipses of the sun

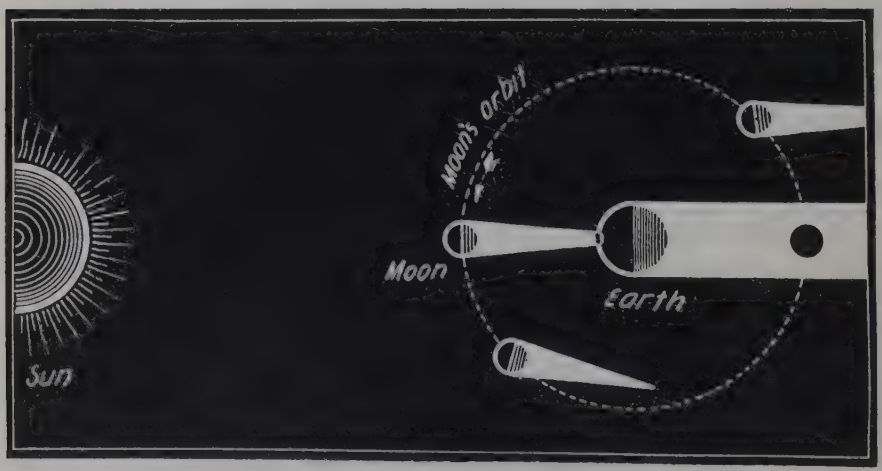
Sometimes the sun and moon are so placed with respect to the earth that the moon's shadow-cone cannot quite reach the earth, and then we have what is called an annular eclipse of the sun, from the Latin word *annulus* meaning "ring." The moon cannot entirely hide the sun from view, and we see a thin ring or annulus of light completely surrounding the dark body of the moon.

Number of eclipses in a year

Every year there must be at least two eclipses of the sun six months apart, and there may be as many as five eclipses of the sun in a year. In addition, there may be eclipses of the moon, which will be seen when the moon is full, two weeks before or after the time of the solar eclipses.

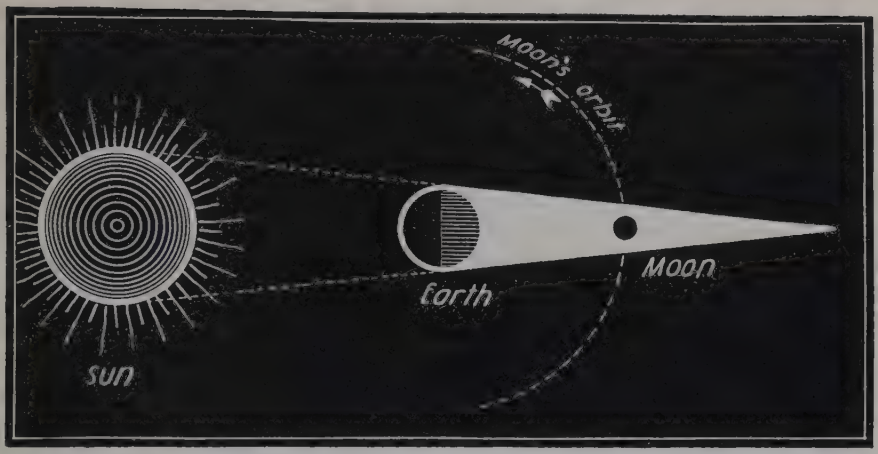
The greatest number of eclipses, of the sun and of the moon, that can occur in one year is seven.

When only two eclipses of the sun occur in any year they must both be either total or annular. When there are more than two eclipses of the sun in a year, one or more of them must be partial eclipses only; that is, only the larger penumbral shadow-cone will fall upon the surface of the earth; the narrow umbral cone within which a



ECLIPSE OF THE SUN *Courtesy Science & Invention*

Here we see how an eclipse of the sun occurs when the moon passes directly between earth and sun and an eclipse of the moon when the moon passes through the shadow of the earth. The shadows of the moon and of the earth are shown in white here.



Courtesy Science & Invention

ECLIPSE OF THE MOON

In this illustration we see the rays of the sun cast upon the earth. The side of the earth turned away from the sun casts a black shadow (shown here in white for contrast) out into space which envelops the moon whenever it enters this shadow, causing an eclipse of the moon.

total eclipse is seen will not strike the earth's surface in such cases.

Eclipses of the Moon

An eclipse of the moon occurs when the earth passes directly between sun and moon and throws its shadow over the surface of the moon.

Eclipses of the moon can occur only at time of full moon, just as eclipses of the sun can occur only at time of new moon.

If the eclipse of the moon is total, the moon passes completely into the shadow of the earth, and so wide is the earth's shadow at the point where the moon enters it that the moon may be totally eclipsed for as long as two hours. A partial eclipse of the moon occurs when the moon is only partly within the shadow of the earth. Sometimes the moon dips only a little way into the earth's shadow and out again. In such eclipses only a partial eclipse of the moon can be seen.

How Does the Moon Look at Total Eclipse

At the time of a total eclipse of the moon it is not completely lost to view in the earth's shadow but shines with a weird, coppery light. This comes from the sunlight that shines through the earth's atmosphere into the earth's shadow, and brightens the moon's surface with its light. If we were on the moon at the time of a total eclipse, we would see the sun completely hidden by the huge, black ball of the earth, but around this black globe would be a narrow, brilliant ring of light—sunlight shining through our atmosphere—which extends to a height of at least 100 miles above the earth's surface.

Why Eclipses Do Not Occur Every Month

Since there is a new moon and a full moon every month, one might wonder why we do not have eclipses every month. The path in which the moon is going around the earth is tipped to the plane of the earth's path around the sun. Therefore, ordinarily, the moon passes so far above or below the line connecting earth and sun, each month at new and full moon, that eclipses cannot occur. Twice a year, though, the moon passes through its "nodes," which are the two points

where its orbit meets the plane of the earth's orbit. When the moon is at, or close to, its nodes, sun, moon and earth get in line *all in the same plane* and then eclipses are bound to occur. If the nodes never changed in position eclipses would occur in the same two months every year but the nodes are gradually shifting their position backward along the ecliptic, or path of the earth around the sun; and so eclipses occur about ten days earlier each year, in two seasons, separated by six-month intervals, which are known as "eclipse seasons." Then, and only then, can eclipses of sun and moon occur.

What is the importance of eclipses

Eclipses of the moon are not of great importance to the astronomer. Neither are partial eclipses of the sun. A total eclipse of the sun, however, is an event of the greatest scientific interest and importance, and expeditions are often sent halfway around the world to observe one. A total eclipse of the sun is also one of the most beautiful and awe-inspiring sights that man can witness. It is only then that we get a glimpse of the magnificent and mysterious solar corona, that outer envelope of the sun, of pearly white, with long streamers extending millions of miles into space.

It is the corona that astronomers are particularly anxious to observe and study and photograph. Its origin is still a puzzling problem, as is also its connection with the solar prominences and sun spots, of which we will have more to say later. There are also one or more strange elements in the corona, particularly "coronium," which is so named because it has been found only in the solar corona. The astronomer is anxious to find out the nature and the origin of that mysterious substance.

Some years ago a strange element was found in the sun. It was called helium, from *helios*, Greek word for "sun," and a number of years later it was also discovered in our own planet, Earth. This is the gas with which our airships,* such as the *Los Angeles*, are now inflated, and it has turned out to be an element of great value to man. It is possible that coronium, which is now found in the solar corona only, may also some day be discovered on our own planet.

*An airship is a lighter-than-air flying machine.

Total eclipses of sun rare at any one place

Though total eclipses of the sun occur nearly every year, they are seen at rare intervals at any one place. Sometimes several hundred years pass by without the occurrence of a total solar eclipse in certain localities. London has not had a total eclipse of the sun since the year 1715 and may not have another for several centuries to come. Some out-of-the-way corner of the globe may be visited by two fine total solar eclipses within a few years of each other. The path of a total eclipse is very narrow, usually less than 100 miles wide, and the chances are against its passing over the same place twice.

The shortness of total solar eclipse

The length of a total solar eclipse is very short. It can never be more than seven minutes and fifty-eight seconds, and it is usually not more than two or three minutes. Into these few fleeting moments the astronomer must crowd all his observations of the sun's corona and other important scientific observations that can be made only at that time.

It is surprising, though, how much can be done in two or three minutes by a number of skillful, carefully trained observers with a battery of telescopic cameras and other instruments. A large number of very valuable photographs of the corona and

other scientific records of eclipses have been collected within the past sixty years or more. The study of these records and photographs will add very greatly to our knowledge of the sun and the way in which its light and heat affect our own planet.

THE TOTAL SOLAR ECLIPSE OF JANUARY 24, 1925

The eastern part of the United States was visited by a very important eclipse of the sun on January 24, 1925. This eclipse was total in one of the most thickly populated parts of the United States, including a large part of New York State, New York City, Long Island, Connecticut and parts of New Jersey, Rhode Island and Massachusetts. It was the first total eclipse of the sun to visit this section since the year 1806. The path of the total eclipse also passed over the Great Lakes, the bordering states, and parts of Canada. Though clouds were general in the Great Lakes region and western New York, the total eclipse was viewed over almost all of its path from Ithaca, N. Y., eastward to Nantucket, in skies of crystal clearness. Very valuable observations were made at a number of observatories that lay directly in its path, particularly at the Wesleyan University Observatory at Middletown, Conn., where a large number of the leading scientists of the United States had gathered with many scientific instruments for observing the eclipse.

It is estimated that fully ten million people viewed this total eclipse, and the greatest interest and enthusiasm in observing the eclipse was shown everywhere. How different from the days when men fled terror-stricken and trembling to hide in cellars on such an occasion, as so often happened in the Middle Ages!

It has been said that this eclipse will go down into history as the best observed of all eclipses up to the present time. Observations of very great value were obtained at many points. These results are now being studied by many scientists, in the hope of discovering more about the secrets of the sun.

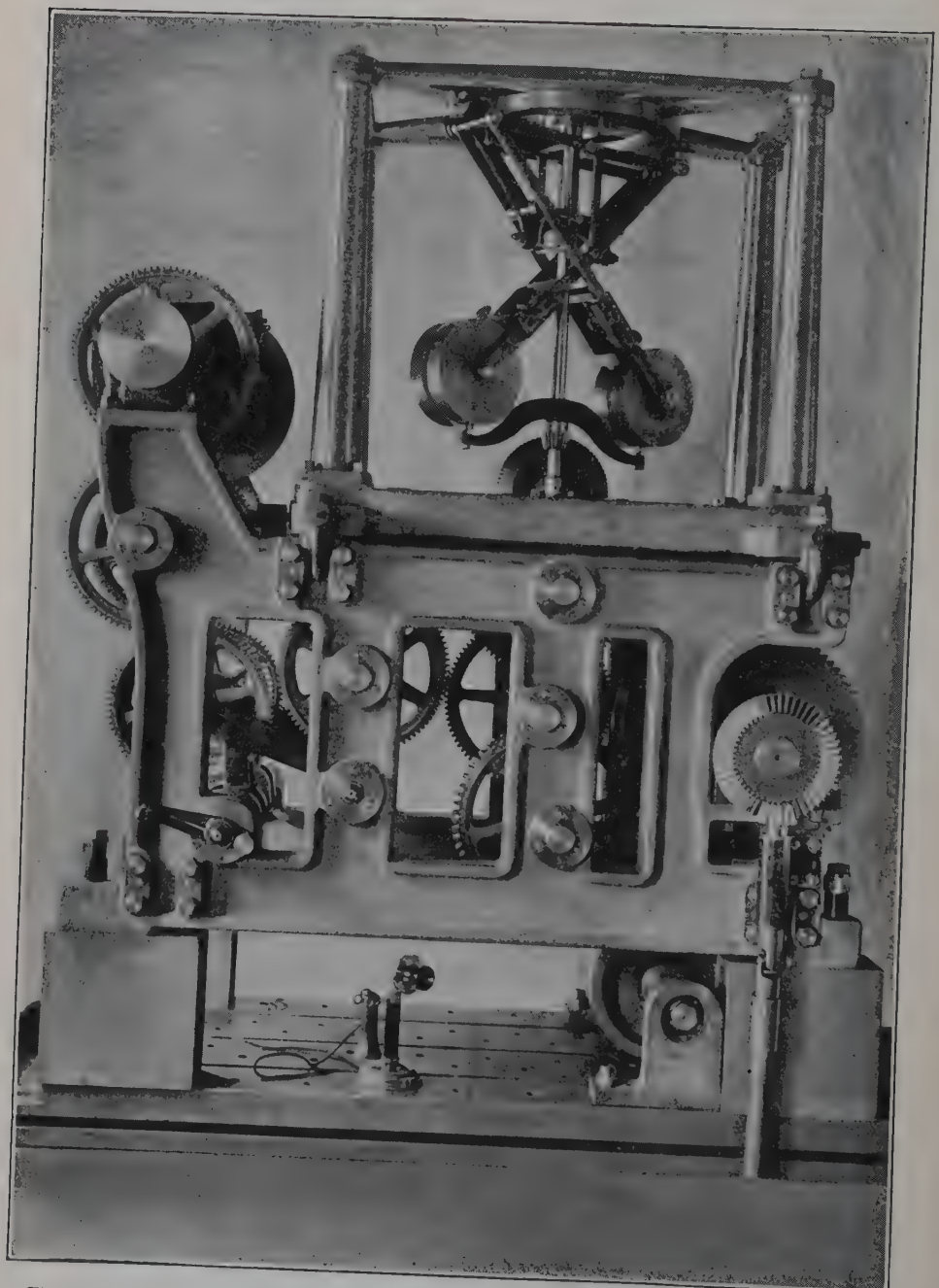
SOLAR CORONA

The pearly radiance of the corona surrounding the sun is shown in this photograph, made by F. Slocum, of the Van Vleck Observatory, during the total eclipse of the sun, January 24, 1925. (Compare with photograph on Page 86.)

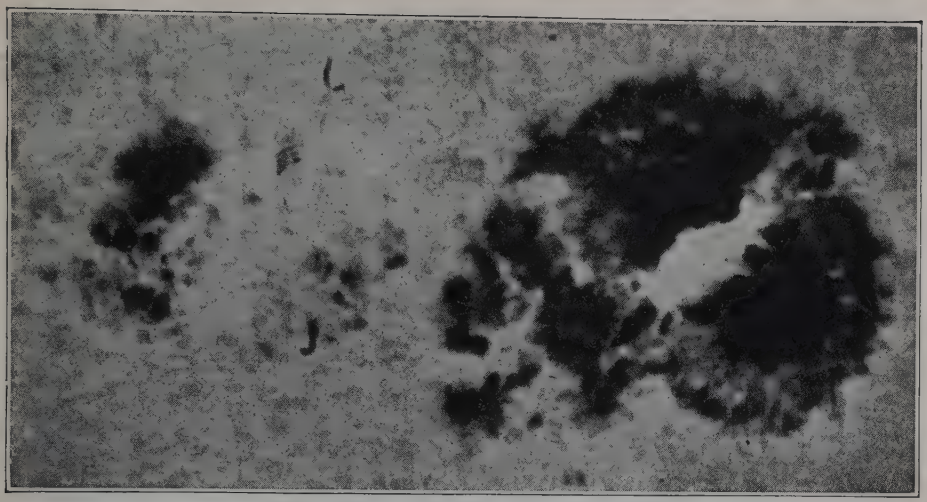
When the Greek historian, Herodotus, wrote of the prediction of an eclipse by the famous astronomer Thales, he marveled that Thales predicted "even the year" in which the eclipse occurred. Thales would be a sorry astronomer, indeed, in these days if he could not predict the coming of an eclipse correctly within a few seconds and the position of its path within a fraction of a mile.

Such is the exactness and freedom from mistakes of astronomy of today, that the predicted time of the coming of the eclipse of January 24, 1925 was correct within five seconds of time. The position of the southern limit of the path of total eclipse, which it had been said would cross Central Park in New York City, fell very near the predicted position. The path of the total eclipse of August 31, 1932, passed over New England and was successfully observed where clouds did not prevent

THE CLOCK THAT DRIVES THE TELESCOPE



This clock is six feet high and five and a half feet square. It was built in the Pasadena instrument shop of the Mount Wilson Solar Observatory to drive the 100-inch reflecting telescope. Note the size of the telephone in comparison.



THE GREAT SUN SPOT OF JULY, 1905

The brilliant streak across the dark spot is called by astronomers a "bridge." It was 20,000 miles in length. Sun spots are dark only by contrast with the brilliant visible surface of the sun. Photographed by Philip Fox with the Yerkes 40-inch telescope.

THE SUN

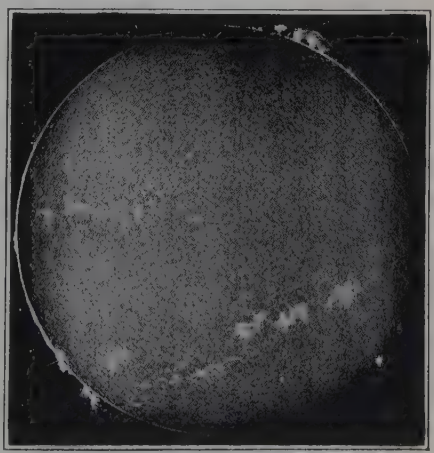
THE sun is the star nearest to the earth. It appears different from other stars simply because it is so near to us. If it were as far away as some of the brightest stars it would be barely visible without the aid of a telescope. For our sun is not even one of the largest or most important stars. It is, however, very important to us, because without its light and heat we would soon die. All life on our planet depends on the light and heat of the sun and the air that surrounds the earth. We cannot live without the light and heat that come from the sun.

PLENTY OF ROOM AT THE SUN

The diameter of the sun is 864,000 miles. Our planet, Earth, and the moon in its orbit, at a distance of 239,000 miles from the earth, could be placed at the center of the sun, and all the planets and their moons and the asteroids in addition could be packed away inside of the sun, and there would still be plenty of room to spare within its interior. The earth is but a tiny speck compared with the sun, no greater in size than some of the small spots on the sun's surface that cannot be seen without using a telescope.

SURFACE OF SUN TWICE AS HOT AS ANYTHING ON EARTH

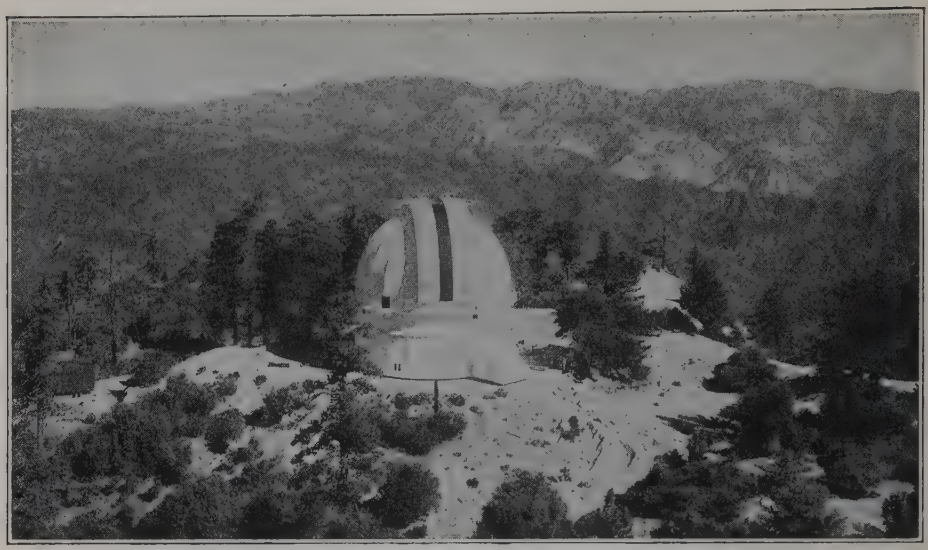
The sun is so hot that no heat that is known on earth can compare with it. The hottest temperature that can



Courtesy Yerkes Observatory

THE SURFACE OF THE SUN

The visible surface of the sun is known as the "photosphere." It has a mottled appearance, brilliant flecks against a less brilliant background. Dark spots, sometimes large enough to be seen without a telescope are sun spots.



HOME OF A GIANT TELESCOPE

Dome of the 100-inch Hooker reflecting telescope, Mt. Wilson, seen from the top of the 150-foot tower telescope shown on Page 87.

be obtained on earth, that of the electric furnace, is about 3,000 degrees, Centigrade. At that temperature all substances turn to glowing vapors except a few compounds, oxides and hydrides, that are very difficult to vaporize. On the sun the surface temperature is about 6,000 degrees, Centigrade, while in the sun's interior the temperature may reach several million degrees. At such a terrific temperature as exists on the sun, all elements—such as hydrogen, iron, sodium and calcium—exist in a free state, mingling as fiery vapors but too hot to combine to form chemical compounds. It is only in sun spots, which are a form of solar cyclones, that the temperature of the sun falls low enough to allow the formation of a few chemical compounds, as for example, magnesium oxide and calcium hydride, which are the same compounds that are so difficult to vaporize in the electric furnace.

THE SAME ELEMENTS FOUND IN THE SUN AND ON THE EARTH

We know that on the earth there are about ninety elements, as they are called, from which all compounds are formed. Some of these we find often in a gaseous state, as oxygen, hydrogen, nitrogen; others in a solid state, as iron, magnesium, calcium, while nearly all of them form chemical compounds with other elements. For example, water is a compound of hydrogen and oxygen in certain proportions, and salt is sodium chloride formed from the two elements sodium and chlorine.

Now, on the sun, it is being discovered, there are the same elements that are found on the earth, the only difference being that on the sun these elements occur in a free, or uncombined, state as fiery glowing vapors.

THE VISIBLE FACE OF THE SUN—THE PHOTOSPHERE

The visible surface of the sun is known as the photosphere. If we look at the photosphere with a telescope, we see it has an odd, mottled appearance. Brilliant flecks, like "rice grains," are seen, 100 to 500 miles in diameter, against a less brilliant background that appears grayish by contrast. They are

believed to be regions where the temperature is higher than that of their surroundings. They may be the summits of hot rising currents from the sun's interior, while the darker regions in between are cooler descending currents.

WHAT ARE SUN SPOTS

The dark spots that appear so often on the photosphere, singly or in groups, and sometimes large enough to be seen without a telescope, are called sun spots. People used to have strange ideas about them. Some thought they were holes through which we could see into the sun's interior. Now it is known that sun spots are solar storms, whirling cyclones of tremendous size. The dark, central area, which may be large enough to engulf our own planet, Earth, in the whirl or vortex of the cyclone, is called the umbra of the spot. The outlying region, much greater in area, is called the penumbra. The umbra of the sun spot may be anywhere from about 500 to 50,000 miles in diameter and the penumbra may be as great as 100,000 or 200,000 miles in diameter.

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HOW BIG IS THE SUN

This illustration gives us a measure of the size of the sun. If the sun was a hollow sphere, you could place the earth in the center and the moon could still revolve in the same orbit that it has now. We would then have almost 200,000 miles left over for good measure. In other words, the earth with the moon and the latter's entire orbit does not even fill out the sun. But turn to Page 97 to see what a giant sun is like.

Sun spots appear dark because they are regions of lower temperature than their surroundings. The temperature is about 3,000° to 4,000°, Centigrade, or only about half that of the normal sun surface, so that, against the brilliant background of the sun, they seem dark by contrast. If the hotter and more brilliant background were not there they would shine brightly.

How the Sun Spots Appear in Eleven-Year Cycles

Sun spots appear in eleven-year cycles and there are maximum periods and minimum periods.

SOLAR PROMINENCES

Photographed during the total eclipse of the sun on January 24, 1925, by F. Slocum, Van Vleck Observatory, Middletown, Connecticut. This photograph was timed to show prominences without the corona. (See photograph on Page 81.)

When there is a sun spot maximum period the sun's face is rarely free from spots for weeks at a time; but when there is a sun spot minimum period, days and weeks may pass without the appearance of a single spot.

The sun, like the planets, turns on its axis. It takes about twenty-five days for it to complete one rotation. Therefore, sun spots appear at one edge of the sun; are carried across the disk by the sun's rotation, and disappear at the other edge about two weeks later. A spot may last through several rotations of the sun or it may disappear in less than one.

The Chromosphere—A Rosy Ring of Light

Directly above the visible surface or photosphere of the sun is the rosy ring of light known as the chromosphere which may be seen at the time of a total eclipse of the sun. This is a dense atmosphere of fiery glowing gases surrounding the sun 5,000 to 10,000 miles in depth.

Its beautiful, rosy tinge is due chiefly to the hydrogen gas that is found in the chromosphere in great abundance, and which is a brilliant scarlet in color. All the elements that have been discovered in the sun appear in this dense lower atmosphere of the sun.

The Great Cloud-Shaped Masses That We Call Solar Prominences

The sun is a place of violent eruptions and disturbances. Sun spots are one sign of this great activity of the sun, and solar prominences, rising from the chromosphere, are another. Flaming tongues of fiery vapors, chiefly hydrogen, helium and calcium, rise constantly from the chromosphere to great heights above the surface of the sun. Sometimes "quiescent," or resting prominences as they are called, float for days like enormous clouds above the sun's surface, taking many fantastic and beautiful forms like clouds in summer skies. Yet these prominences are so enormous in size that our planet, Earth, would be lost like a small ball in them.

Erupting prominences, unlike the quiet kind, keep darting upward from the chromosphere to heights of thousands of miles, more rarely to heights of 100,000 miles or over, with speed that may be as great as 100 miles a second or more. Their form may

change completely in half an hour or less. They are one of the most beautiful features of a total solar eclipse. Hydrogen prominences are a deep scarlet in color, and at the time of an eclipse appear beyond the dark rim of the moon like flaming mountains of strange and weird forms.

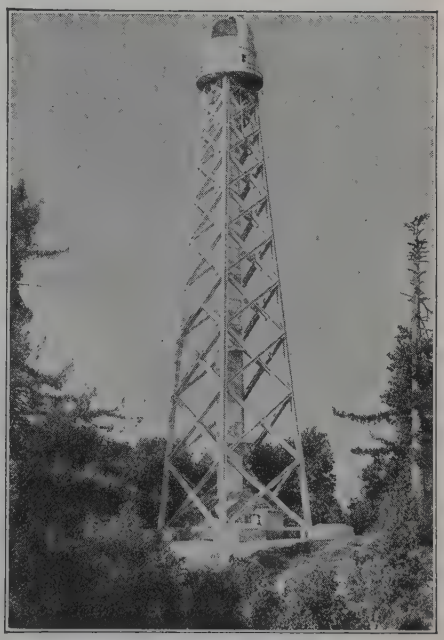
THE OUTER ENVELOPE OF THE SUN—THE CORONA

The sun's corona or outer envelope is so faint that it cannot be seen so long as any light from the surface of the sun remains visible. Therefore, we can see the corona only at the time of a total eclipse of the sun, when the moon hides the brilliant rays from the surface of the sun. This outer envelope of the sun is composed of delicate rays and streamers, extending millions of miles into space. They change in form during the eleven-year sun spot cycle. When the surface of the sun is greatly spotted the corona has one form, and when there are few sun spots it has another. The astronomer has learned to recognize these different shapes that the corona takes at different times from observations of many total solar eclipses.

The cause of the change of the corona in form in the eleven-year period is not yet known. That is one reason why astronomers are anxious to make all possible observations of the sun at times of total solar eclipses.

WHAT HAS THE SUN TO DO WITH THE EARTH'S ATMOSPHERE

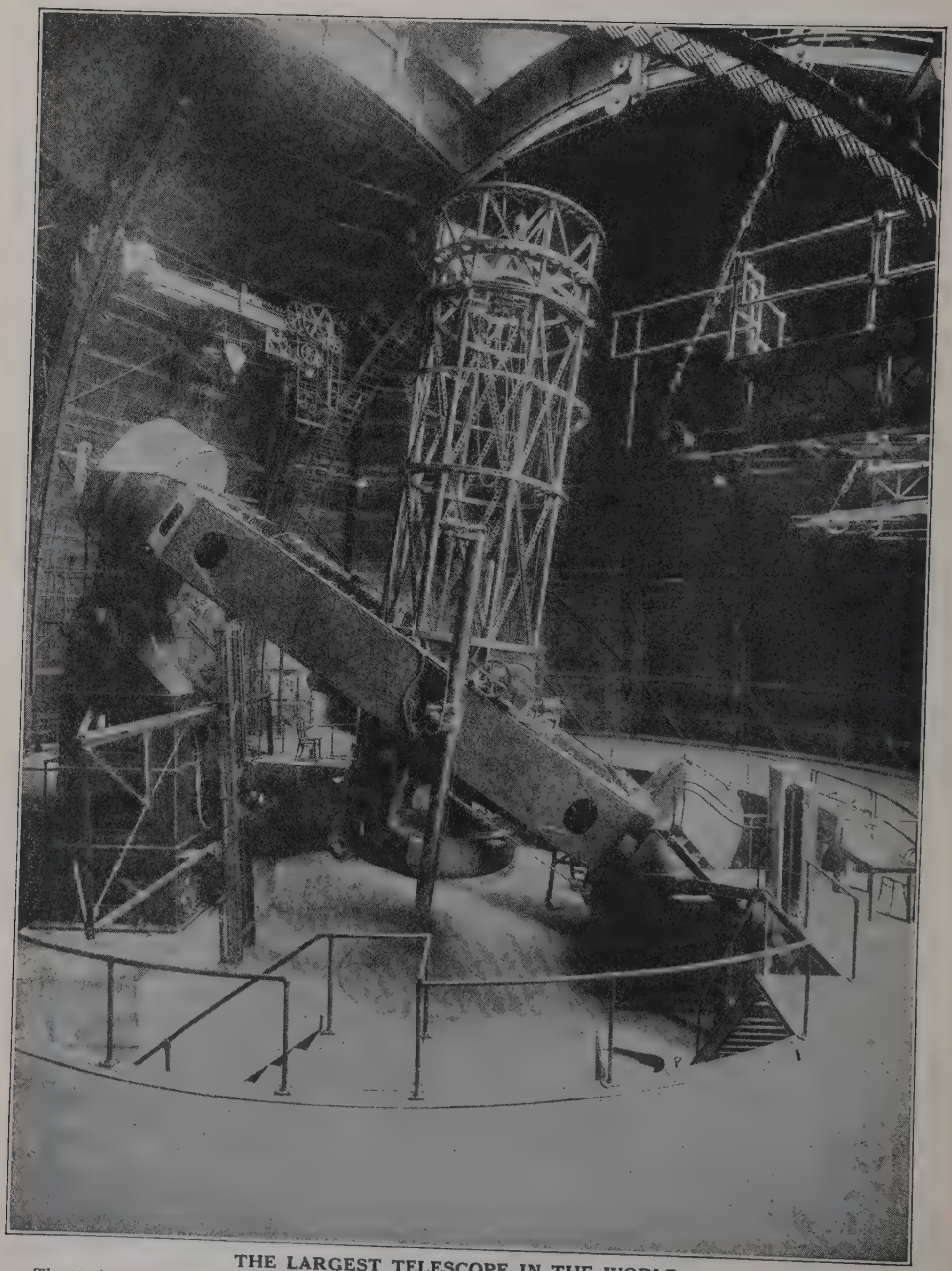
It has been found that there is some connection between disturbances in the earth's atmosphere and change in the activity of the sun. The appearance of large sun spots or great solar prominences are sometimes followed by great displays of the Northern Lights, and interrupted radio or telegraphic communications, and at times, temperature changes. There are powerful magnetic and electrical forces at work in the sun that directly affect the earth's atmosphere. Electrified particles are shot forth from the sun with great force at such times. These enter our atmosphere, and probably that of other planets as well, it is believed, and disturbances of many kinds result.



TOWER TELESCOPE

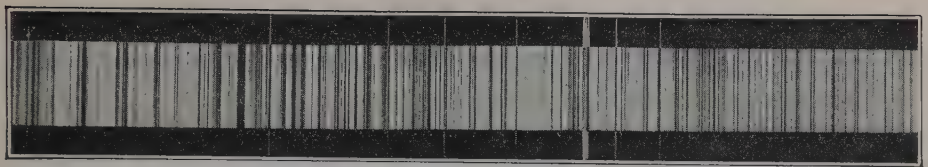
Photographs of sun spots, prominences and all other solar phenomena are taken with this 150-foot tower telescope at Mt. Wilson Observatory, California.

In recent years some astronomers believe they have found a connection between changes in the weather and variations in the amount of light and heat which the sun gives forth. Dr. C. G. Abbot, of the Smithsonian Institution, and other astronomers working with him have been making weather forecasts from measurements of the changes in the radiations of light and heat from the sun with some very good results. This may lead in time to a new and valuable way of foretelling changes in the weather.



THE LARGEST TELESCOPE IN THE WORLD

The 100-inch Hooker reflecting telescope with which observers at Mt. Wilson, California, can bring the images of the farthest stars down to the earth for their careful inspection.



THE SPECTRUM — REVEALER OF THE SECRETS OF THE STARS

The light of a star passed through a prism produces a series of lines on a background of color, known as a spectrum. The lines of the spectrum reveal to those who can read the story almost all that is known about stars —composition, temperature, and even the direction in which the stars are moving. The one shown here is the spectrum of Alpha Boötis (Arcturus).

THE SOLAR SPECTRUM

YOU may wonder how it is that the astronomer knows that nearly all of the elements, such as iron, sodium, calcium and hydrogen, that are found here on earth, exist also in the sun and stars.

Possibly you have heard of the solar spectrum and that wonderful little instrument, the spectroscope, which unlocks the secrets of the sun and stars.

WHAT IS THE SOLAR SPECTRUM

The solar spectrum is a band of different colors, that is formed when a ray of sunlight is passed through a glass prism. You can see it in nature in the rainbow, in which each drop of water acts as a tiny prism. A ray of sunlight is really made up of a bundle of rays of different colors—red, orange, yellow, green, blue, indigo and violet —which are called the colors of the spectrum. When a ray of sunlight is passed through a glass prism the rays of different color are more or less bent from their course, red the least and violet the most. They are all spread out in a beautiful band of color, red at one end and violet at the other. Each color blends gradually with the color next to it, so that the band is continuous or unbroken from the red to the violet. Next to the red rays in the invisible part of the spectrum are the infra-red or heat rays, as they are called, and beyond the violet rays the ultra-violet rays. Though our eyes are not sensitive to the infra-red or ultra-violet rays, they can be studied in many ways, especially by photography. The photographic plate is very sensitive to the ultra-violet rays, so that they can be photographed. It has also been found that if photographic plates are dyed in certain solutions they will be sensitive to the infra-red rays.

THE FRAUNHOFER LINES OF THE SOLAR SPECTRUM

There are many lines in the spectrum and the most important of all are the dark or "Fraunhofer lines," as they are called. These are the lines that tell us of what sun and stars are made.

If you look at the spectrum that is formed by passing sunlight through a glass prism, you will see a very great number of fine, dark lines crossing the band of different colors. These include the lines of all the gases and vapors that are to be found surrounding the surface of the sun—that is, in its atmosphere.

The continuous band of color in the spectrum comes from the sun itself, but the dark lines belong to its atmosphere. They are dark because the gases in the sun's atmosphere are cooler than the gases from the photosphere or surface of the sun, which gives the continuous band of color. They appear dark by contrast with their hotter background, just as sun spots appear dark at the surface of the sun, because they are at a lower tem-

perature than the surrounding surface of the sun.

If you could take away the brilliant background of the sun's surface, the dark, or Fraunhofer lines, would be seen shining brightly against a dark background. This is just what happens at the beginning and ending of a total solar eclipse, when the moon has covered the sun's surface, but the sun's atmosphere still remains uncovered. The "flash spectrum" then appears for a second. The lines that are usually dark in the solar spectrum flash forth brilliantly against a dark background at the edge of the sun for an instant as the sun's surface disappears behind the moon. This is only for a second, though, for soon the moon covers the atmosphere as well as the surface of the sun.

How the Dark Lines of the Solar Spectrum Tell the Secrets of the Sun

If you take some table salt (sodium chloride), and heat it in the flame of a Bunsen burner until it turns to vapor, and then let the light from this glowing vapor pass through a glass prism, you will see two bright yellow lines close together against a dark background. Again, if the light of some glowing hydrogen vapor is passed through the prism, you see four lines, some distance apart, on a black background—a red line, a bluish-green line, a blue line and a violet line. Iron vapor, in the same way, gives thousands of lines of different colors. In every case the lines of each element are different in position and appearance from the lines of any other element. Each line, moreover, corresponds in position to some dark line in the solar spectrum. For example, in the solar spectrum, there are two dark lines that are in the same position in the spectrum as the two bright yellow lines of sodium that appear when the light from glowing sodium vapor is passed through the glass prism. The only difference is that the bright sodium lines appear against a dark background, while the dark sodium lines in the solar spectrum appear against the bright band of continuous color belonging to the surface of the sun.

In the same way there are four dark lines in the solar spectrum that correspond exactly in position to the bright lines of the glowing hydrogen vapor when its light is passed through the glass prism.

No two elements, it has been found, have any lines in common. Every element has its own peculiar or characteristic line or group of lines, and often some of these lines are in the infra-red or the ultra-violet part of the spectrum.

The astronomer has mapped the positions of nearly all the dark lines in the solar spectrum, and compared them in position and number with the bright lines of the different elements that have been studied and mapped in the laboratory. In this way he has found that most of the elements here on earth also exist in the atmosphere of the sun. There, however, they are in the condition of highly heated vapors, while here at the earth's surface they are usually combined with other elements as solids, liquids or gases at low temperature.

The Spectroscope and the Secrets It Reveals

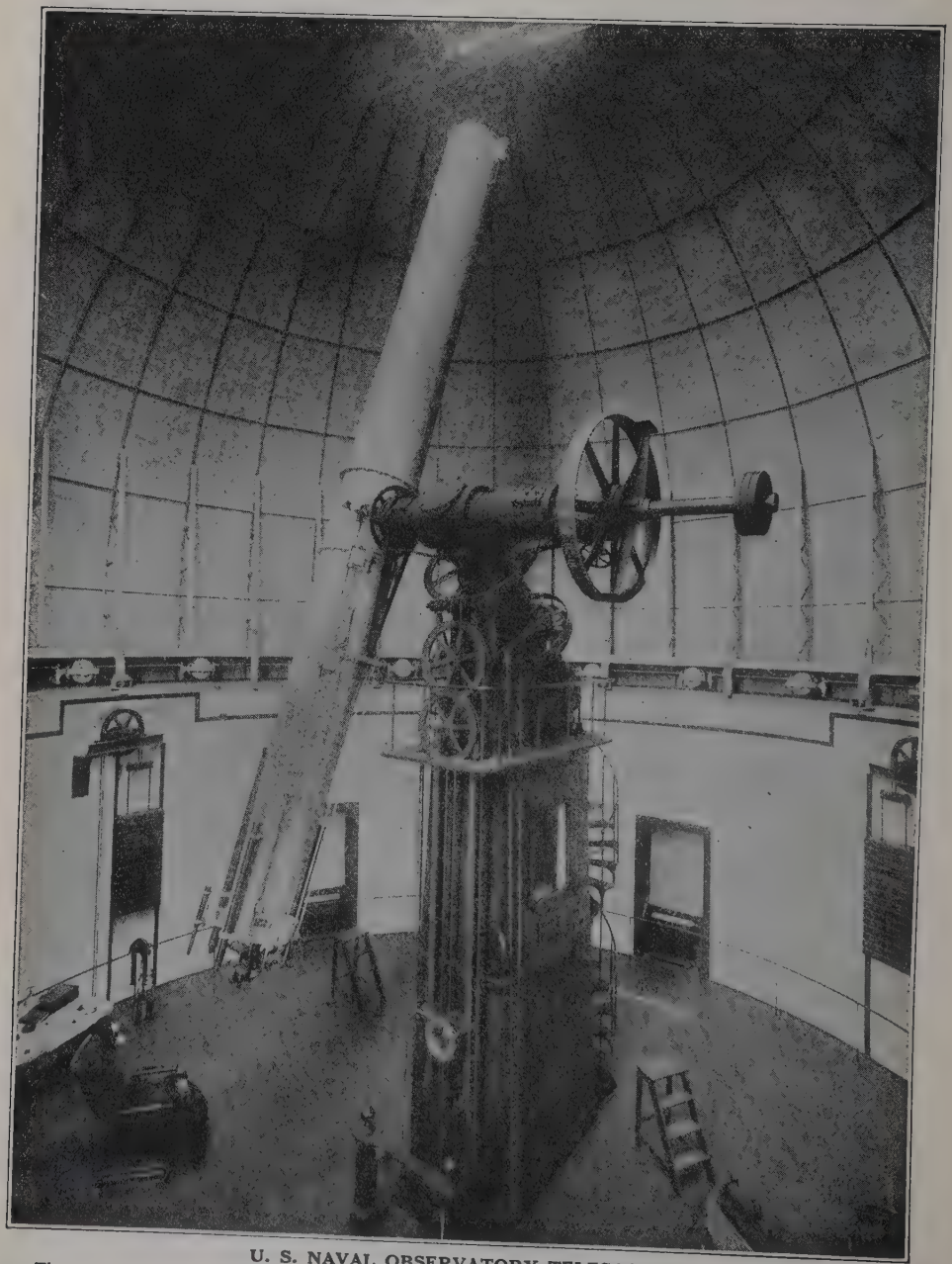
One of the most wonderful instruments of astronomy today is the spectroscope, with the aid of which the solar spectrum and the spectra of the stars can be studied. The all-important part of the spectroscope is the glass prism, or some similar device for separating the rays of different colors and forming a spectrum of the sun or of the stars. For the stars also have spectra crossed with dark lines, in

LICK OBSERVATORY

The Lick Observatory, Mt. Hamilton ,California, taken from the east. This gives a splendid view of the mountain.

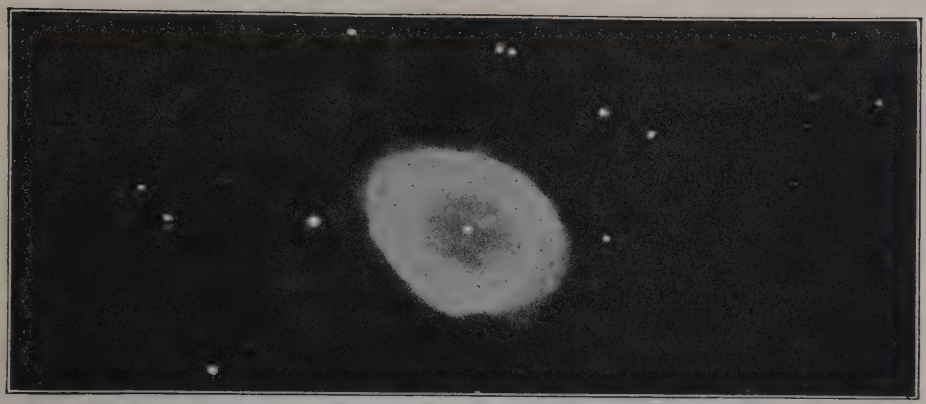
some cases very like those of the sun. With the aid of the spectroscope, it is possible to find out what gases and vapors are in the atmosphere of the sun and stars.

The dark lines in the spectra of sun and stars often shift in position. If the star is moving toward the earth, all the dark lines in the spectrum shift slightly toward the violet end of the spectrum, and if the star is moving away from the earth, the lines all shift toward the red end of the spectrum. The amount of the shift shows how rapidly the body is moving toward or away from us. Sometimes these dark lines split temporarily into two or three lines, showing that they are in a strong magnetic field. Again, they may become bright temporarily, showing that for the time they are hotter than the bright background of sun or star. And so we might tell of many secrets that the spectroscope reveals. Most of the wonderful things that have been learned about the sun and the stars in the past fifty years or so have been discovered from the study of the spectra of sun and stars by means of the spectroscope. The name of "The New Astronomy" is given sometimes to that new and fascinating field of discovery that has been opened up in recent times with the aid of this modest-looking little instrument attached to powerful modern telescopes.



U. S. NAVAL OBSERVATORY TELESCOPE

The twenty-six-inch refracting telescope at Washington with which the satellites of Mars were discovered by Asaph Hall, Sr., in 1877.



A MIGHTY CURIOSITY OF THE SKIES—LYRA, RING NEBULA

In the center of this ring form nebula is a star. From this star, in the opinion of scientists, goes forth the gaseous matter that makes the cloudlike mass, or nebula.

IN THE DEPTHS OF SPACE

THE stars we know are suns, fiery balls of glowing gases and vapors of many elements, like our own sun. That they appear as mere points of light even in the most powerful telescopes, is due to their tremendous distances from the earth, which are almost beyond our understanding.

How far away are the stars

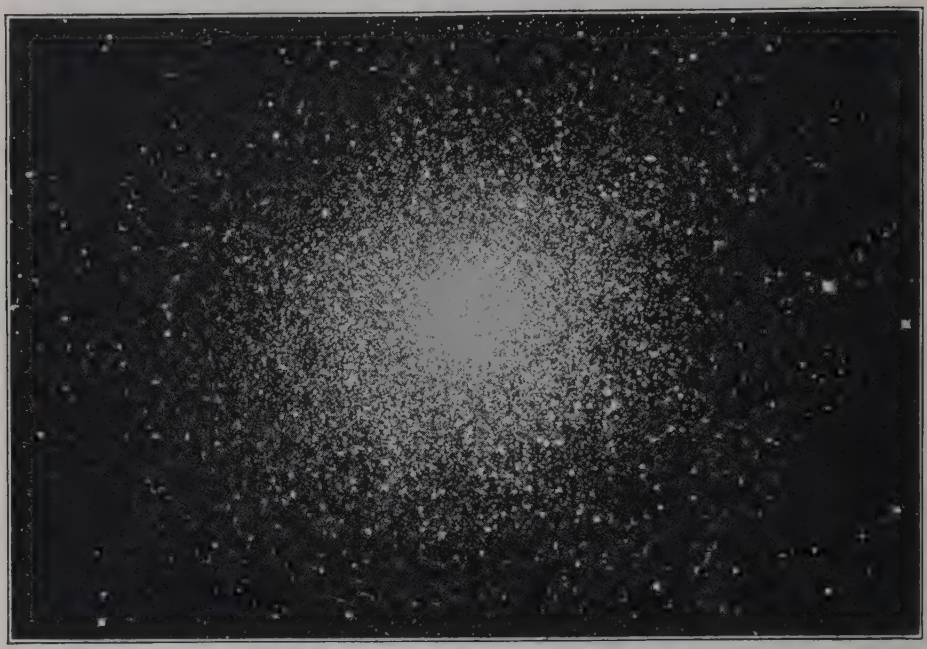
If we should undertake to make a small model of the solar system and its surroundings, in which we should represent the distance from earth to sun as one inch, how far away do you think we should put the stars? The extent of the solar system would be about five feet. The nearest star, Alpha Centauri, on this scale of 93,000,000 miles to the inch, would be four and one-third miles distant. Other very near stars would be anywhere from ten to one hundred miles away. The great majority of the stars could not be shown at all in this little model of the heavens for they would have to be placed at distances of many thousands of miles beyond the earth. The most distant known object, the Great Andromeda Nebula, would be a million miles away.

The light year

When it came to measuring star distances the astronomer soon found that he would have to use a new unit. To express the distances of the stars in miles would give numbers so large that

MOST DISTANT KNOWN OBJECT

The great spiral nebula in Andromeda, photographed by G. W. Ritchey, Yerkes Observatory, with the 24-inch reflector. This object, just faintly visible to the naked eye, is believed to be at least 900,000 light years distant. Some astronomers regard it as the Milky Way of an independent star system.



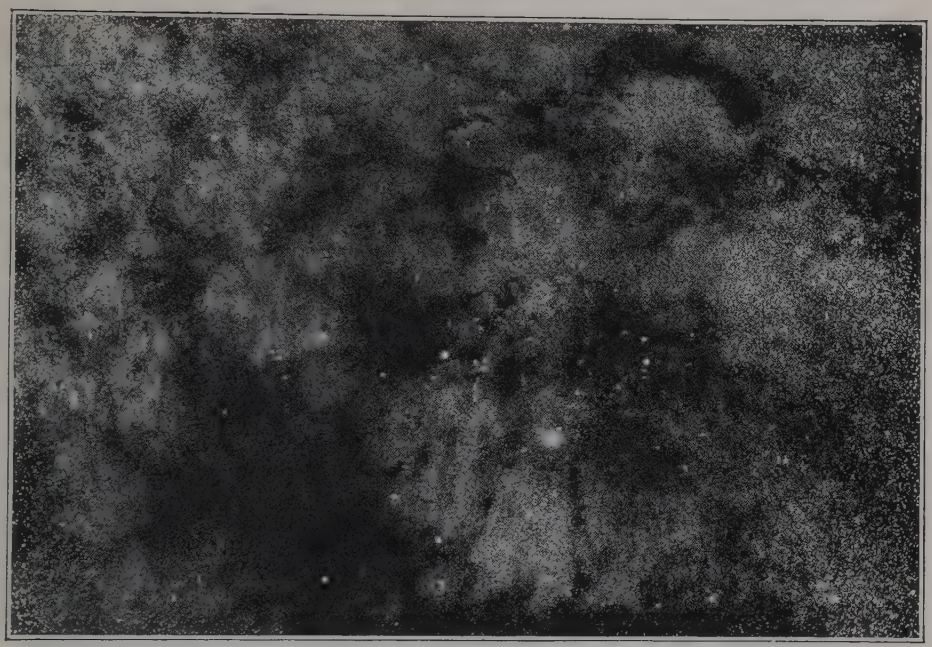
GREAT HERCULES STAR CLUSTER
The great star clusters are among the most beautiful objects in the heavens.

we could not understand them, so the light year came into use. This is the distance that light travels in a year at the rate of 186,324 miles per second. It is equal to nearly six million million or six trillion miles. Light from the nearest star, which is four and one-third light years distant, takes four and one-third years to pass over the distance that separates the star from the earth.

The distance of a star from its nearest neighbor is, on the average, several light years. So, although all the stars are moving onward through space in various directions, there is ample room for each star to go its way without hitting or even coming close to any other star. Our own sun, we know, has been going onward through space at the rate of twelve and one-half miles a second for at least several billions of years without striking or closely approaching any other star in the heavens. Such a disaster, we know, would mean the destruction of our own planet, Earth, and the other planets of the solar system, and in the earth's crust there exists proof that the earth has been in existence as a planet for several billion years at least.

How many stars in the sky

Some years ago a well-known astronomer gave some seemingly good reasons to show why there could not be an unlimited number of stars in the heavens. Star counts and estimates were made of the number of stars within reach of the most powerful telescopes, and estimates were also made of the additional number of stars that were too faint to be seen even with the aid of telescopes. It was concluded that there must be close to two billion stars, all told. As it was said, there was a star in the heavens for everyone in the world, for the popula-



Courtesy Yerkes Observatory

A PART OF THE MILKY WAY

The broad belt of stars that we call the Milky Way appears to the naked eye as a light haze, but the telescope shows it to be composed of millions of faint stars. This view, the region of Theta Ophinchi, has an S in the center. Can you find it?

tion of the world is nearly two billion. Today, however, astronomers have very good reason to believe that there are many times two billion stars in the sky. It is probable that there are at least several hundred billion stars rather than two billion. One noted astronomer of today has shown that it is even possible, after all, that the number of stars may be unlimited.

Stars differ in apparent brightness

As you know, stars appear to differ from one another very greatly in brightness. The astronomer has made a scale by which stars can be compared in apparent brightness. In this scale, a star of one magnitude differs about two and one-half times in brightness from a star of the next magnitude. For example, a star of the first magnitude is two and one-half times brighter than a star of the second magnitude, while a star of the second magnitude is, in turn, two and one-half times brighter than a star of the third magnitude, and so on. A difference of five magnitudes makes a difference of one hundred times in brightness. That is, a first magnitude star is one hundred times brighter than a sixth magnitude star and a sixth magnitude star is one hundred times brighter than a star of the eleventh magnitude. A first magnitude star, then, would be 10,000 times brighter than an eleventh magnitude star. The faintest stars that we can see without a telescope are the sixth magnitude stars. The stars of higher magnitudes are seen only in telescopes and the faintest stars seen in the greatest telescopes are stars of the nineteenth or twentieth magnitudes. Some of the brightest stars visible to the naked eye are even brighter than first magnitude stars. There are stars of zero magnitude that are about two and one-half

times brighter than the first magnitude stars. All of the magnitudes are divided into tenths and hundredths so that we have such magnitudes as 1.45 or 15.5 so as to show very slight differences in the brightness of the stars. There are two stars, Sirius and Canopus, that are even brighter than zero magnitude stars.

How stars differ in true brightness or light-giving power

In general, the nearer stars are the brighter, and the most distant are the faintest. But we cannot say this is always true of *any* two stars in particular. Some very faint stars are close neighbors of the solar system. Sirius,

THE GREAT ORION NEBULA

The most celebrated nebula in the heavens—an enormous mass of glowing gases whose size challenges the imagination. Its dimensions can be measured only by the tremendous yardstick of light years. Photographed at Mt. Wilson.

on the other hand, is a brilliant star, considerably brighter than Rigel in Orion, but Sirius is only about nine light years away and Rigel is 650, and in actual size and light-giving power Sirius is a pygmy compared to Rigel. If it were as far away as Rigel it would be a very insignificant star in appearance. So we cannot say that any one star is brighter than another, or is bigger than another, just because it appears brighter. We must first know how far away two stars are before we can compare them, either in true brightness or in size. Stars differ from each other as greatly in their true brightness or light-giving power as they do in their apparent brightness.

Stars of different temperature

Probably you have often noticed how the stars differ in color. There are bluish-white stars, such as Vega and Rigel, white stars like Altair and Fomalhaut, yellow stars like Capella and red stars like Antares or Betelgeuse.

Have you ever noticed how a bar of iron changes in color when it is heated —from glowing red to white heat? It is the same way with the stars, the hottest are the bluish-white stars, while those of lowest temperature are the reddish stars. Various ways have been found to measure the heat, and it is known that the average temperature of the red stars runs from 3,000° to 4,000°, Centigrade; of the yellow stars such as our own sun, 6,000° to 7,000°, Centigrade; of the other yellow stars, 10,000° to 12,000°, Centigrade. The hottest of all, the intense bluish-white stars, may reach temperatures as high as 15,000° to 18,000°, Centigrade. These are all surface temperatures. Far within their interior the temperatures of the stars must rise to millions of degrees.

Measuring the bigness of the stars

In recent years it has been possible actually to measure the diameters of a few of the largest stars. This is done by means of an interferometer, which is an instrument for measuring the interference of light, as its name suggests. By means of the interferometer attached to the great 100-inch telescope of the Mt. Wilson Observatory, the angular (measured by an angle) diameters of a number of stars have

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THE GIANT STAR BETELGEUSE

If the star Betelgeuse was a hollow sphere it could enclose comfortably our own modest little Sun, the planets Mercury, Venus, Earth, and there would still be plenty of room for these planets to revolve in their present orbits. Compare the giant sun, Betelgeuse, with our own, shown on Page 85.

been found. If the distances of the stars from the earth are known, it is then possible to express these angular measures in terms of miles.

STARS THAT ARE GIANTS AND STARS THAT ARE DWARFS

The results of measurements of the diameters of several stars with the interferometer have shown that there are giant stars so enormous that if they were put at the center of our solar system they would extend to or beyond the orbit of Mars. With such suns at the center of our solar system, there would be no room for the planets Mercury, or Venus, or even our own Earth. The orbits of these three planets would lie beneath the surface of such giant suns as Antares or Mira or Betelgeuse, if they occupied the position of our own sun.

The greatest of all giant stars, so far as is now known, is Antares, with a diameter of 400,000,000 miles; Mira, or Omicron Ceti, comes second with a diameter of 250,000,000 miles, and Betelgeuse, third, with a diameter of 215,000,000 miles. Other giant stars are Beta Pegasi, 150,000,000 miles; Aldebaran, 30,000,000 miles, and Arc-

turus 20,000,000 miles. Compare with these great suns our own modest little sun with its diameter of 864,000 miles and our tiny planet with its diameter of 8,000 miles! The diameter of the earth's orbit is 186,000,000 miles or less than the diameters of the stars, Antares, Omicron Ceti and Betelgeuse.

In various ways astronomers have been able to learn a great deal about the size and distances of many of the stars, and it is now known that there are many dwarfs, as well as giants, among the stars. Our own sun is a yellow dwarf star, and the brilliant Sirius that outshines all the stars owes its splendor to its nearness rather than its size, for it is classed among the dwarfs, with a diameter not much greater than that of our own sun.

The red giant stars owe their brightness to their huge size rather than their light-giving power; for, compared with the brilliant white stars, area for area of surface, they shine much more feebly and are much cooler bodies.

How the Stars are Born, Grow Old and Die

It was once believed that the stars were born of bright, gaseous nebulae—vast, whirling masses of glowing vapors. It was believed that these nebulae gradually condensed into white stars. It has been discovered more recently, though, that the nebulae do not, in general, shine by their own light, but only by the reflected light of stars with which they are associated, or by electrical excitement which is produced by these stars. In an unexcited state, and in the absence of bright stars in their midst, the nebulae are dark—composed, possibly, of fine, dust-like particles of matter whirling through space in vast clouds. They often appear standing out against a background of stars as dark markings, especially among the dense clouds of stars in the Milky Way.

The stars now are believed to begin life as red giant stars, forming from these dark nebulae and growing hotter gradually, as they contract. As they continue to increase in temperature they pass through the stage of being yellow giants to that of brilliant white or bluish-white stars. Then they are at the height of their splendor. After passing through that stage of life they begin to lose heat, instead of gaining it, and their intense white color fades first to yellow and then to red. They are then in their old age as red dwarf stars, and soon they join the ranks of the dark stars, that we know must exist, but which we cannot see.

The life of a star from the red giant stage to the red dwarf stage is measured in billions of years it is believed. A million years in the life of a star is but as a day in the life of a man.

Size and Form of the Great System to Which Our Sun Belongs

The sun is but one star, with its satellites, in a vast system of stars, of which the Milky Way, or Galaxy, is the foundation, or backbone, as we might say.

The Milky Way is that broad belt of stars encircling the heavens, whose light appears to the naked eye as a light haze, but which the telescope shows to be made up of millions of faint stars. It has long been known that the majority of all the stars in the heavens crowd toward the Milky Way, which forms a vast watch or lens-shaped system of stars. The diameter of this vast gathering of stars is estimated to be over three hundred thousand light years, but its depth is not more than a few thousand light years.

How the Stars Journey Through Space

Within this enormous system of stars, which the astronomers call our galactic system, the stars move in streams and drift to and fro—our sun

among them. The speed with which the different stars are moving varies, but in general it is between five and twenty miles a second. Some of the stars travel singly, though possibly, like the sun, they may be attended by small dark satellites similar to the planets. Others have companion stars. These are the double, triple or multiple stars that appear as single stars to the naked eye, but are split up by the telescope into two, three or more stars whirling rapidly around a common center as they speed onward through space.

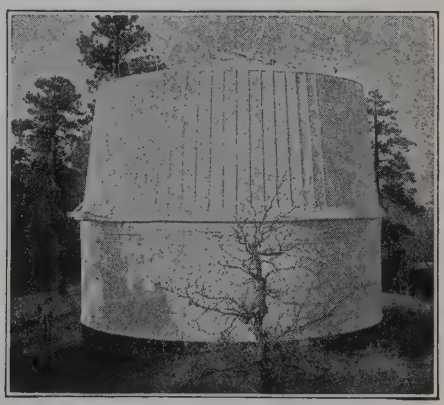
Many stars belong to large, moving groups or clusters of stars of great size. The Pleiades form such a cluster, and five of the stars of the Big Dipper and the brilliant Sirius are among the members of another group, known as the Ursa Major cluster.

In addition to the hundreds of millions of stars that make up this enormous system of stars to which our sun belongs, there are the vast gaseous nebulae such as the Great Orion Nebula and the Network Nebula in Cygnus. In addition, there are all the strange, dark streaks and markings in the Milky Way that are known as the dark nebulae. These dark, nebulous clouds shut off the light from stars beyond, and are made up of finely divided meteoric dust, similar possibly, to the meteoric dust particles that enter our own atmosphere as meteors or shooting stars.

Beyond the Milky Way

Far beyond the Milky Way system of stars to which our sun belongs, lie the Magellanic Clouds, the round or globular star clusters and the spiral nebulae.

The Magellanic Clouds are two hazy patches of light near the south pole of the heavens, that look very much as if they had been flung off from the Milky Way. They lie far outside of the Milky Way system of stars, however, and are not in any way connected with it. The distance of the Smaller Cloud from the earth has been found to be about 100,000 light years, and its diameter is about 5,000 light years. The Greater Cloud is at a distance of 110,000 light years, and its diameter is about 14,000 light years. Powerful telescopes show that these clouds are very like our Milky Way system of stars in their nature. Countless points of light represent suns in these enormous systems and, as in the Milky Way, there are vast gaseous nebulae, some luminous and some dark. All of the stars that are visible in these Clouds are giant suns, for, at a distance of 100,000 light years, a star no brighter than our own dwarf sun would be hopelessly invisible even in the greatest telescopes.



PART OF LOWELL OBSERVATORY
Dome of the 24-inch refracting telescope.

The globular star clusters are among the most beautiful objects in the heavens. Imagine a starry ball of numberless points of light, each a sun far away in the depths of space at distances of many thousand light years. Many of the stars in these clusters and in the clouds of which we have just spoken are the remarkable Cepheid

variable or changeable stars. The name Cepheid comes from the fact that one of the first stars of this kind to be studied was Delta Cephei, a star in the constellation of Cepheus. These stars vary in brightness in short periods of a few hours, days, or weeks, with the regularity of clockwork. Imagine tiny points of light in distant balls of stars increasing and decreasing continually in brightness, as if their light changes had been timed by the clock! The strangest and most important thing about the Cepheids is that the periods of the light changes of these stars depend upon their true brightness, or light-giving power. All Cepheids are giant stars; but the ones that have the longest periods of light changes are the most luminous, and the ones of shortest periods are the least brilliant. Now, it is a fact of very great importance that when we know the *true* brightness of a star, as in the case with these Cepheid variable stars, we can tell how far away that star is if we measure its *apparent* brightness. As you know, when two candles of equal brightness are at different distances from us, the more distant candle appears fainter than the nearer one. By measuring the difference in the apparent brightness of the two candles, it is possible to tell how much farther away one is than the other. So it is with the light of the stars; if we know that a Cepheid star has a certain definite brightness, we can tell how far away it is by measuring its apparent brightness.

We have told you about the Cepheids because they are of such importance to the astronomer. These Cepheids are found in the Magellanic Clouds, globular star clusters, and some of the spiral nebulae. Whenever the astronomer finds them in such objects he can find their distance from the earth, though they may be at distances of hundreds of thousands or even millions of light years. Other stars of known brightness, such as the red giant stars, are also found in these far-away objects, and help in telling their distances.

Most interesting of all objects in the sky are the wonderful spiral nebulae, which are found by the hundreds of thousands, and which are now known to be so far outside our Milky Way system of stars that they must form great systems of stars like the Milky Way.

The name "island universes" has been given to these vast assemblages of suns that lie so far beyond our own star system that their light takes hundreds of thousands or even millions of years to reach us. Some of the spirals are so faint, because of their great distance from us, that even in the most powerful telescopes they can be seen only as faint, hazy, little patches of light. The largest and brightest and probably the nearest of all the spirals is the Great Nebula in Andromeda, which is visible even to the naked eye as a cloudy patch of light. It has been discovered recently that this nebula is at a distance of nearly a million light years from the earth. It is the most distant known object in the heavens, though there are, no doubt, many faint spirals that are far more distant.

There are still vast unexplored regions in space that lie far beyond the reach of our greatest instruments. As Columbus, when he sailed westward, extended the limits of the then known world, so the astronomers of today are extending the limits of the known universe. The great Mt. Wilson reflector, the largest telescope in the world today, has brought into view millions of suns unknown before. Even larger telescopes are now being planned, still further to extend our vision into space.

UNITED STATES NAVAL OBSERVATORY

Our time signals are sent out from the Time Service Department of this great observatory at Washington, D. C.

MEASUREMENTS OF TIME

LONG before history was written, men were taking thought of the division of time. They divided the year and the month and the day and their success in so doing is taken as some sort of measure of their civilization.

Day following night and seasons coming in regular turn were perhaps the first observations that enabled men to measure the passage of time. The animals could do almost as much, however, and man needed better ways of measuring time.

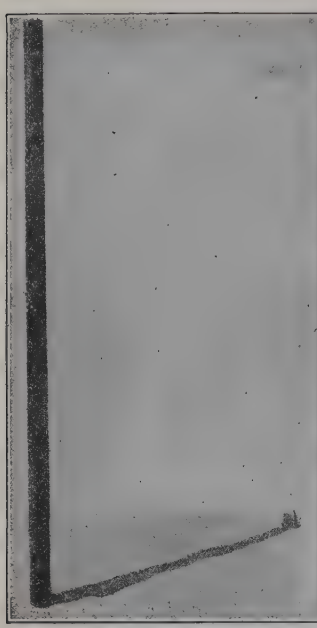
Four thousand years ago the Chaldean astronomers had marked the path of the sun through the heavens and had arrived at the idea of twelve months. They also divided the lunar month into days and the days into hours and minutes. To the Chaldeans sixty and its multiples were sacred numbers. There were twelve hours in their days and three hundred and sixty seconds in each hour. Three hundred and sixty days made their year. Their calendar, with certain improvements, is ours. The old calendar was five or six days short each year. It had twelve lunar months of thirty days each, but twelve lunar months do not make a year.

How flattery changed the calendar

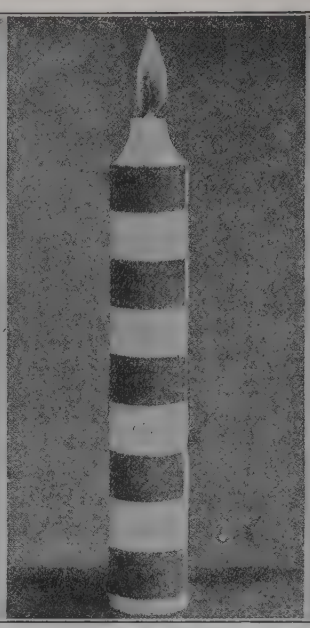
Julius Caesar had the calendar changed so that the year should consist of six months of thirty days and six of thirty-one days each. This amounted to a total of three hundred and sixty-six days and was nearer being correct. The astronomers found that this arrangement made the year a bit too long, so they provided that one of the thirty day months (February) should have but twenty-nine days with the full thirty days only once in four years. This made the calendar very nearly correct.

Caesar's nephew, the Emperor Augustus, or some of his flatterers, tampered with the calendar, not to improve it but to compliment Augustus. The month in which his birthday fell they called August. His month of August then had thirty days and it seemed uncomplimentary that the month of the "divine Augustus" should have one day less than July,

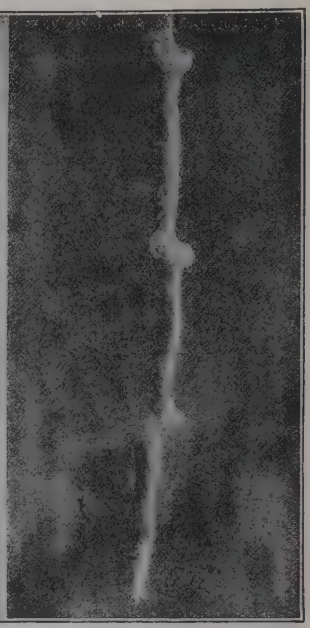
TIME RECORDERS IN CLOCKLESS AGES



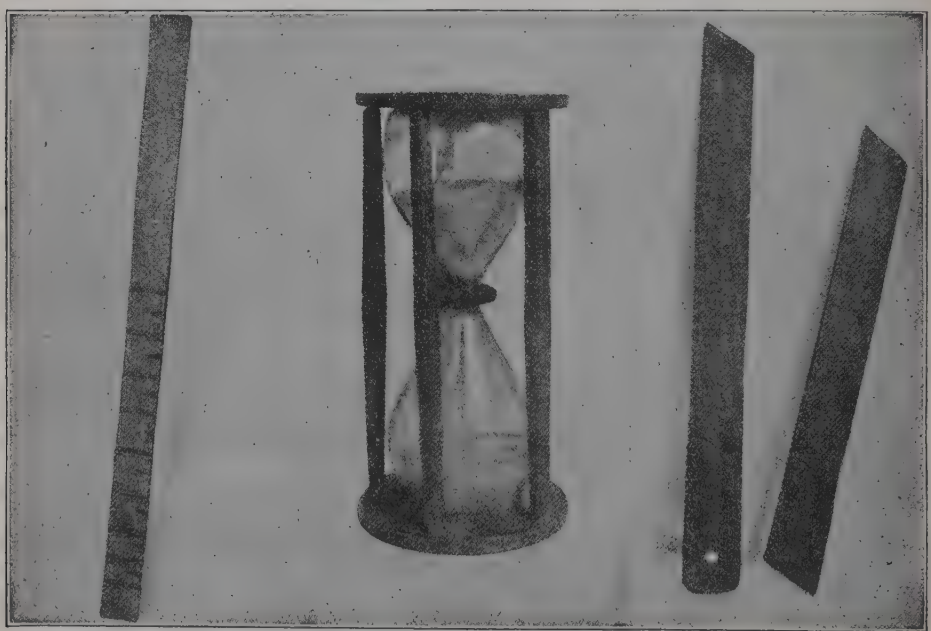
This was one of the first ways in which men told the time, fixing a stick upright in the ground and marking the spot reached by the shadow. This moves round the stick, becoming shorter before noon and longer after.



At night men marked a candle in equal sections in black and white, so that each section was burned in a given time. Alfred the Great is said to have invented this way of measuring the passing of time.



Here is a simpler method of telling the time by night. A hemp rope is knotted in regular spaces, and set light to at the bottom, smoldering slowly and regularly. In Korea people still tell time in this way.



Here is a time-recorder. Every time a section of rope or candle is burned through, or an hour-glass turned, the owner cuts a notch on a stick to mark the hours of vigil passed.

This is an hour-glass, like an egg-boiler used in kitchens. One end is filled with sand, which pours through a small hole into the bottom bulb. It was once used to measure sermons!

When a master and man wished to keep a record of time for wages, two sticks were used. The servant brought his part of the stick, and the farmer compared it with his own.

the month of his distinguished uncle. February was robbed of another day and became a twenty-eight and twenty-nine day month. The extra day was then added to August to the glory of the Emperor.

CORRECTING THE CALENDAR UP TO OUR DAY

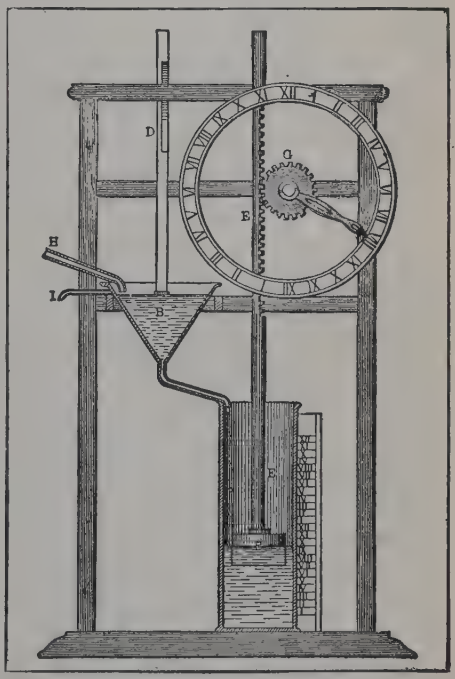
By the time of Pope Gregory XII it was found that the calendar was getting away somewhat from the exact year of the astronomers. A leap year every fourth year was too often. In fact the calendar was ten days beyond the solar year. Ten days were dropped to correct the error and it was decided to drop three leap years every 400 years. The year 1600 was a leap year but the years 1700, 1800 and 1900 were not. The year 2000 will be a leap year. The astronomers figure that it will now be unnecessary to make further changes in the calendar for some 4,000 years.

MEASURING TIME IN CLOCKLESS AGES

Arranging the number of days in the year and dividing days into hours and minutes is not measuring time. The measurement of time so far as years were concerned was taken care of by the astronomers with their observations. The measurement of hours and minutes was a harder problem to solve. Men worked on this for thousands of years before they reached satisfactory answers. It was not until the seventeenth century that a reliable clock was invented.

The best that the Chaldeans could do was to make the sundial. It does fairly well under certain conditions. It will not answer on a cloudy day and it stops work always at sunset. It will work only in the latitude for which it is made. The sundial was widely distributed over the ancient world. King Ahaz had one in Jerusalem. They were used in Egypt, Rome and Greece.

Another important measurer of time was the water clock or clepsydra, a word meaning "thief of water." It was widely used. In its simplest form it was a bucket with a hole in the bottom through which water leaked. If you filled the bucket at breakfast time you might know that it was somewhere near supper time when the last drop ran out. Sometimes the clepsydras were equipped with a dial which responded to the level of a float and marked the hour very much as the indicator on a water tank. Plato brought the first water clock to Greece and Scipio Nasica took the first one to Rome. Caesar is said to have measured the short summer nights in England by a water clock.



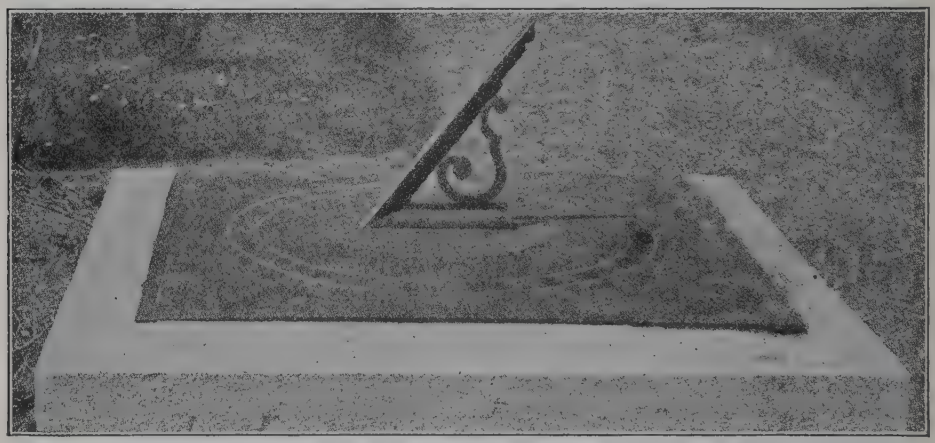
CLEPSYDRA—WATER CLOCK

Through pipe H water runs into B; thence to reservoir F; overflow runs out at I. A rod E actuates a hand which moves over a numbered dial. By raising D the flow of water is increased; by lowering it is made less. Thus the clepsydra may be set for a certain period, a day or night, or adjusted for any time of year. When the reservoir becomes full it must be emptied and the clock reset. (From Milham's *Time and Timekeepers*, Macmillan.)

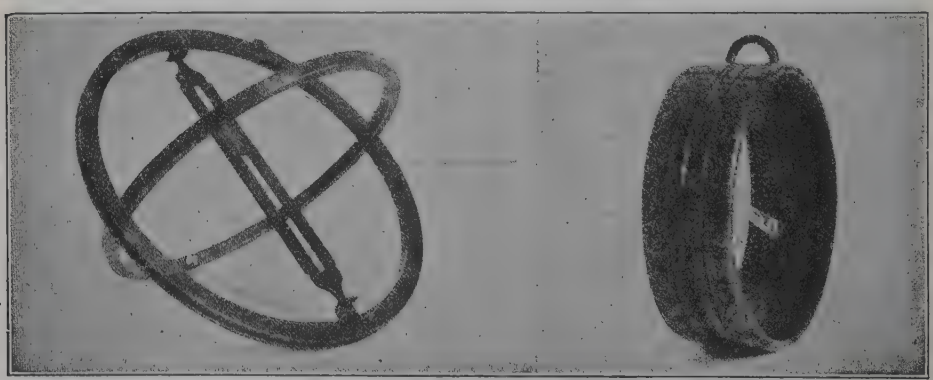
HOW TIME IN PAST AGES WAS MEASURED BY THE SUN

Time was measured for ages and ages by placing a small dish or a round basin in water and boring a hole in the bottom of it, the water flowing in, and gradually sinking it. This would always happen in the same period of time, so that men knew the time when the dish or water-clock sank.

This is a tiny rushlight holder. A rushlight was used before candles were made. It burns regularly, and was used by the poor for a long time after candles were invented.



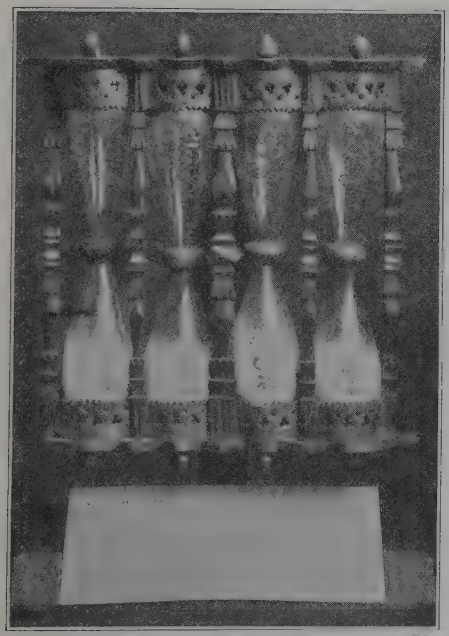
There are very few people who have not seen a sundial, either on a house, or on a pedestal in a park. The dial is marked, and the time is told by the shade of the pointer falling on the different numbers.



This is a kind of movable sundial, which can be held up so that the sunlight shines through a tiny hole in the straight piece of metal, and lights up one of the figures engraved inside of the circle, which is placed at a right angle to the straight piece.

This is a primitive watch. It was always held in one position, and the sun, shining through the little hole, fell upon one of the numbers engraved on the inside of the circle, as shown here.

A thousand years later they were still in use and a king of Persia sent one as a gift to Charlemagne. This water clock had a dial attached and this was composed of twelve small doors, representing the hours. Each door opened at the hour it represented, and out of it came a number of little balls that fell one by one on a brass drum. The hour of the day was shown to the eye by the number of doors that were open. The ear was informed of the time by the number of balls that fell. At twelve o'clock a dozen miniature horsemen came out and closed all the doors.



U. S. Natl. Museum Photo

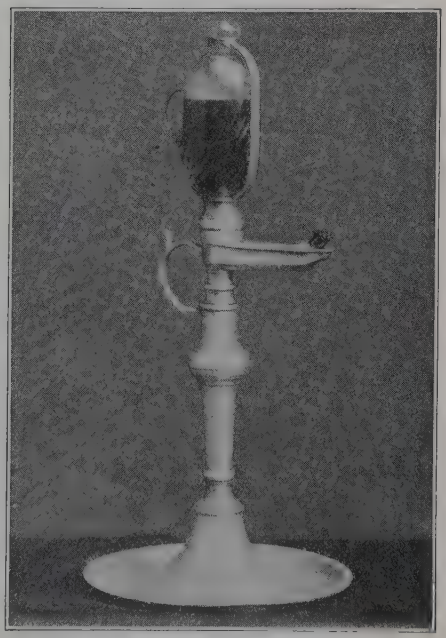
A SET OF SAND GLASSES

Used probably in the fourteenth century in France. The glasses are numbered with old style Arabic numerals.

The Chinese used a burning, knotted rope as a timekeeper. The passage of time was marked as the knots burned. Perhaps this rope placed between a sleeper's toes may have served as the original alarm clock.

Alfred the Great used striped candles which were a foot long and were supposed to burn an inch an hour. A variation of this was the lamp where the wick used oil out of a glass jar marked with the hours. We read of this kind of timekeeper as being used by Philip II of Spain.

The sandglass or hourglass was for thousands of years the most common timekeeper in general use outside the homes of the wealthy. In colonial days the minister would measure his sermons by the flow of the hourglass. Today the careful housewife uses this device in boiling eggs.



U. S. Natl. Museum Photo

TELLING TIME WITH A LAMP

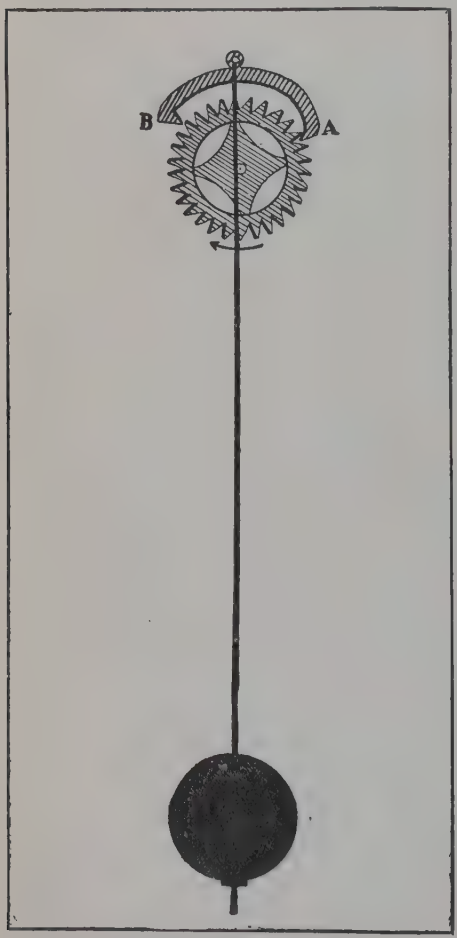
This lamp was used in clockless days. It is of pewter with a glass oil receptacle open at the bottom for oil to feed to the burner. The upright metal band on the receptacle is marked with the hours.

THE ARRIVAL OF THE REAL CLOCK

When we speak of a clock we mean a mechanism consisting of wheels and pinions, or toothed wheels, driven by a weight or spring and regulated by a pendulum or hairspring escapement. An escapement is a contrivance connecting the train of wheelwork with

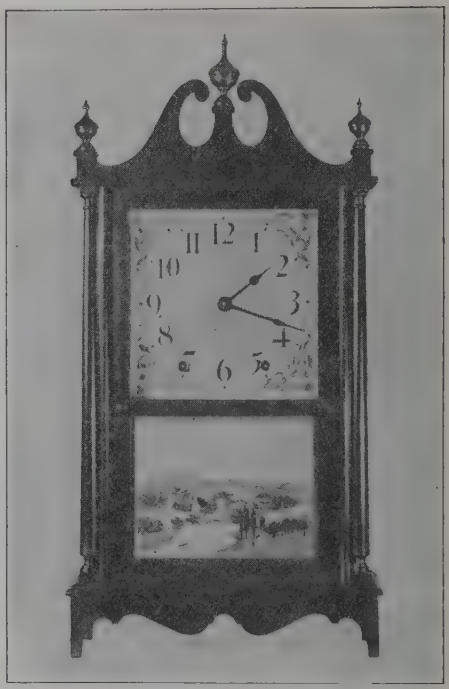
the pendulum or balance, giving the latter the push by which it is kept swinging. The escapement is so called because it allows a tooth to escape at regular intervals. As the tooth escapes, as shown in the diagram, it gives a little push to the pendulum and keeps it swinging. The pendulum does not, therefore, make the clock go as some people suppose. The clock keeps the pendulum going.

Nobody can say who invented the clock. There is some trouble about the very word "clock." For instance, in Germany the word *glocke* means not only "bell," but also our word "clock." A German church may be reported as having had a "clock" when what it had was in fact a church bell which was struck with a hammer when the sundial nearby marked the hour.



ESCAPEMENT AND PENDULUM

As the pendulum swings, a tooth on one side escapes while one on the other side is caught (at A and at B). This action produces the ticking of the clock. The escaping tooth gives a little push to the pendulum which keeps it swinging. (From Milham's *Time and Timekeepers*, Macmillan.)



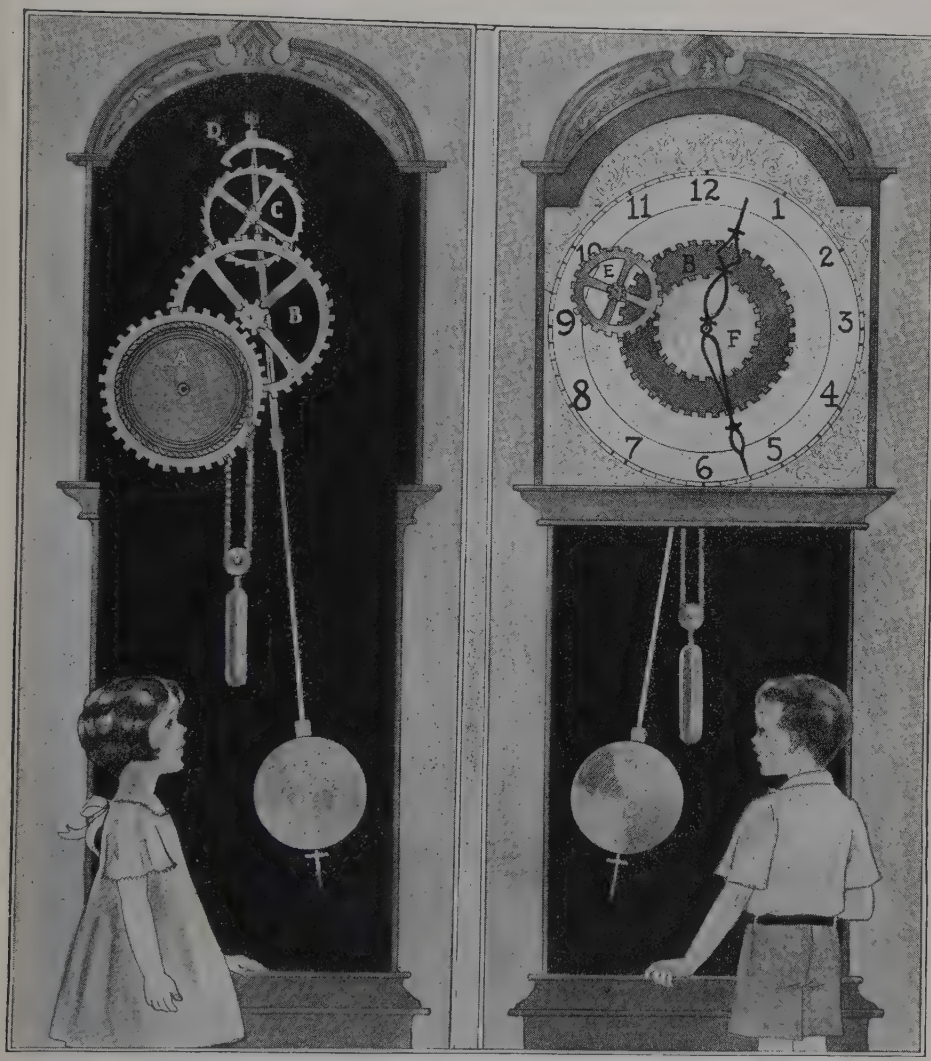
Courtesy Seth Thomas Clock Co.

A COLONIAL CLOCK

There were certainly clocks of a sort in various church towers in Europe in the thirteenth and fourteenth centuries. Most of them were so crude that it was a question whether they told the time or lied about it.

In 1657, Huygens, a distinguished Dutchman, and the man who discovered the rings of Saturn, made or had made a clock which he had designed. It is believed to have been the first pendulum clock. Galileo had discovered some seventy-five years earlier the principle of the pendulum, but it had not been used to control the speed of

WHAT MAKES THE CLOCK'S WHEELS GO ROUND



This picture of the inside of a clock shows us how the wheels go round. It is not the pendulum that makes the clock go; it is either a weight or a spring. In this grandfather's clock it is a weight. The weight is on a cord which passes round a broad wheel, called a barrel, marked A in the picture. The heavy weight pulls the cord downwards, and the cord, being wound round the barrel, pulls the barrel round. The edge of this barrel has teeth which work into the teeth of another wheel, marked B, so that both wheels go round. This second wheel causes the top wheel, marked C, to go round, and so all the wheels are set to work. But if that were all, the wheels would run round too quickly, and they must be made to run slowly and regularly. At the top is a curved piece of metal with a catch at each end; it is called the escapement, and is marked D. This swings to and fro, and every time it swings, it catches the top wheel and prevents it from going round more than one tooth.

This picture shows how the wheels make the hands go round. The three wheels shown in front of the clock, marked B, E, and F, are really behind the face. B, E, and F are necessary for the hands. Wheel F goes round once every hour, and as the minute hand is fixed to it, the wheel carries the minute hand round with it. Now wheel F touches wheel E with its edge, making it go round also. E is a double wheel, having near the center a small wheel fixed to it with only six teeth; it is really on the other side of wheel E, but it is shown in the picture in front for clearness. Each tooth in it fits into a tooth in wheel B, thus making that wheel go round. As wheel E goes round once in an hour, the six teeth in its center carry round one-twelfth of wheel B, which has seventy-two teeth. The hour hand is fixed to wheel B, so while F is going once round it makes wheel E drive B one-twelfth of its journey. Thus wheel F, with the minute hand, turns twelve times while wheel B, with the hour hand, turns once.

clocks. This discovery of Huygens marked the beginning of a new era in the making of timekeepers. By the close of the seventeenth century the clock of fair accuracy had arrived.

The next problem was to get a good clock for use in navigation. It was an age of exploration and the needs of navigators were of the greatest importance. In England a prize of £20,000 was offered and John Harrison, a Yorkshire clockmaker, won the prize for his invention and improvements in the ship chronometers. The English still lead in making this kind of timekeeper.

Making clocks in America

Long before the Revolution clockmaking began in this country. In general, there was a following of the lines established by European makers in so far as the works were concerned. Purely American types of cases were produced. One important thing, however, was accomplished by an American and that was reduction of cost. A Connecticut Yankee, Eli Terry, sometimes referred to as "the Father of American Clockmaking," reduced the price of clocks. He made them in such quantities that it became possible for every one who could afford a home to afford a clock.

Watching clocks

No clock is exact and all clocks must be watched and checked by observations made by the astronomer. The movements of the stars must constantly be used. In the great observatories watchers regulate the astronomical clocks with the greatest exactness. They send out signals by telegraph or radio so that all may regulate their clocks within a second. These signals, by skillful mechanisms, are used even to correct clocks automatically, setting them back or putting them forward. In this way exact time is maintained in all large cities, railroads are run on schedule and the work of the business world proceeds on a reliable time basis.

How the study of the stars enables us to tell time

We have referred to the astronomers as the ones who tell us the exact time. How do they do it? Let us look back through the centuries to the earliest observers of the midnight sky. In those distant days men studied the returning phases of the moon and established moon or lunar months. Among many uncivilized peoples this method is still used in measuring spans of time.

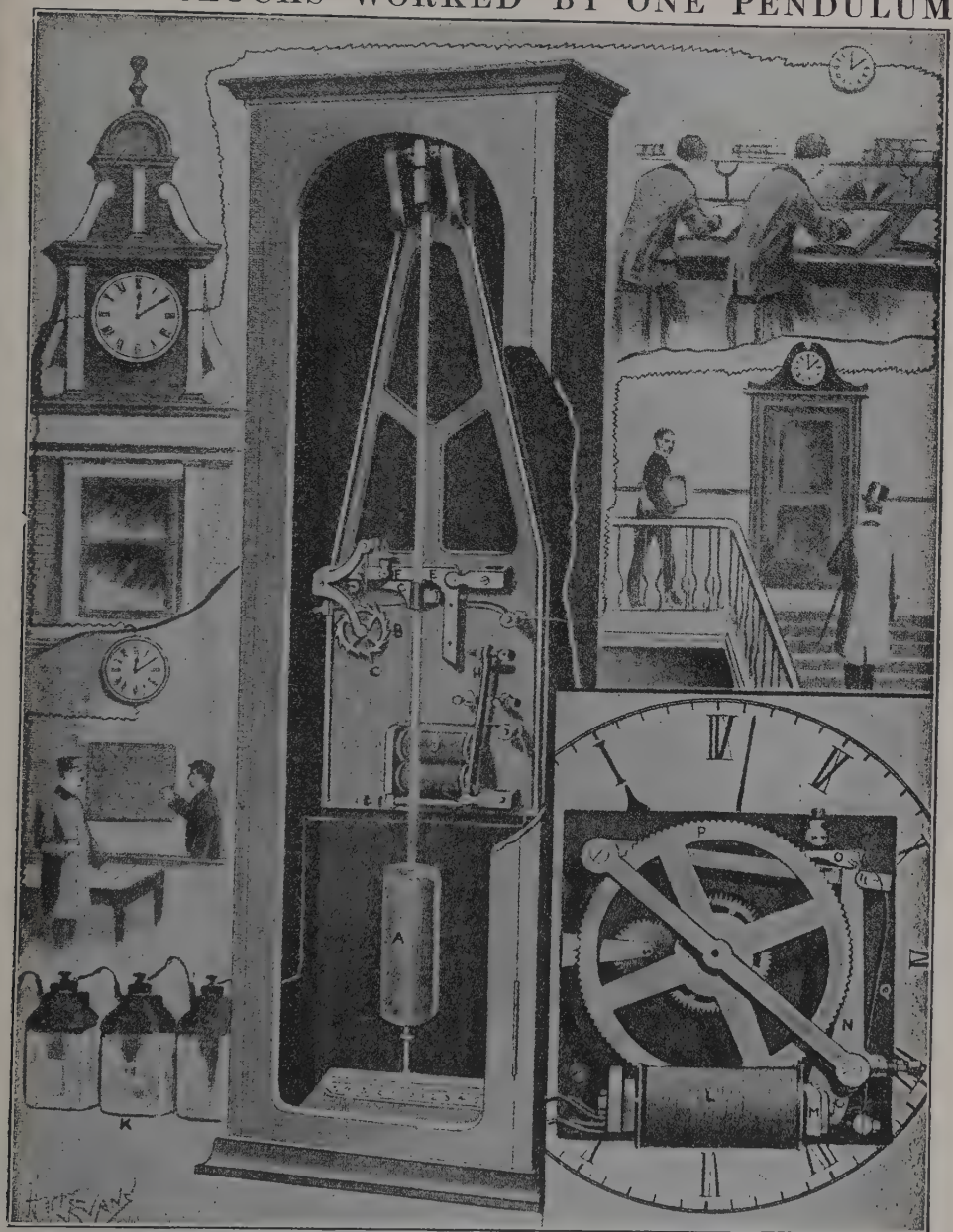
As men studied the sky they saw that the stars were not a jumbled mixture of lights wandering about, but a trained army that marked the passage of time. Against this mighty procession the annual courses of the sun and the moon stood out clearly. Men found that the sun could be regarded as the hand of a yearly clock that showed by its position the month and the season. The sun's path was divided into twelve parts, each corresponding roughly to a month, as we have already learned.

How astronomers of long ago determined time

Two methods were used in telling the time of year. Early rising astronomers noted the last star rising just before the sun. Other observers who perhaps were later risers, did their work in the evenings and connected the sun with the constellation that set just after sunset. After mapping out the yearly and the monthly course of the sun it was easy to study constellations in other parts of the sky.

All this work was done in widely separated parts of the earth, in Chaldea, Babylonia, Egypt, Peru and even in remote China. We cannot say where the oldest astronomical studies were made. It seems certain that about

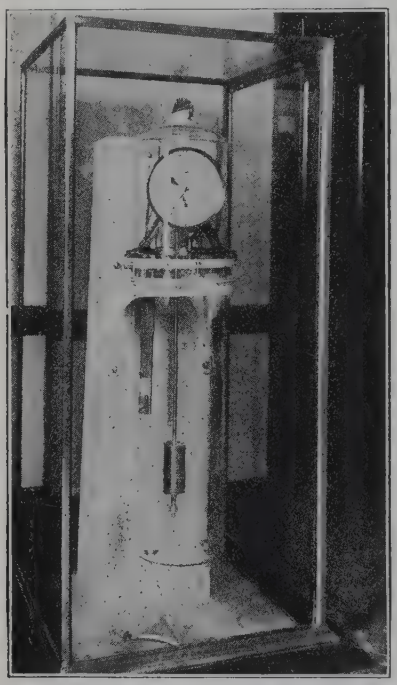
MANY CLOCKS WORKED BY ONE PENDULUM



HOW AN ELECTRICALLY DRIVEN PENDULUM TURNS THE HANDS OF NUMEROUS DISTANT DIALS

By the aid of the electric current all the clocks in a large factory or even a town can today be controlled by a single pendulum. This diagram shows the principle of the synchronome system. The clock consists of the pendulum (A) alone, which pulls round the wheel (B) once every half-minute. The vane (C) then withdraws the catch (D), and allows the gravity lever (E) to fall. The little roller (F) presses the pendulum aside by running down the bracket (G) mounted upon the pendulum. The lower arm of the gravity lever (E) then meets the contact screw in the end of the armature (H), thereby closing the circuit of the electro-magnet (J), which allows the current from the battery (K) to pass through the dials all over the building. These dials are advanced half a minute whilst the electro-magnet (J) attracts the armature (H) and throws the gravity lever (E) up on to its catch again. The clock-faces have no "works" behind them, only one wheel and a magnet, shown on the right. The electro-magnet (L) receives the half-minute impulses, so attracting the armature (M), and by means of the lever (N) enabling the click (O) to pick up another tooth of the wheel (P). The spring (Q) then propels the wheel (P), and the minute-hand attached to it, one half-minute

4,000 years ago the Babylonians fixed and named the principal constellations that mark the yearly path of the sun. These people made the claim that their records went back over 400,000 years. At any rate, with their knowledge they could carry their calculations back-



UNCLE SAM'S CLOCK

The correct time as shown on this clock at the U. S. Naval Observatory is sent forth twice each day by radio and telegraph to all parts of the country. Note how the clock is encased in glass to protect it from air currents and temperature changes. No one clock is used exclusively, however. The rates of several such clocks are determined from observations of the stars and any one of the clocks may be used in sending out the time signals.

ward and so find the position of the sun among the stars during many centuries before their own age.

DIFFERENT KINDS OF TIME AND HOW WE KEEP TIME TODAY

The sun is our natural timekeeper. Its rising and its setting govern our daily activities to a great extent, and our clocks, as we shall see, are regulated to keep "mean sun" time. Mean is used in the sense of average.

We cannot regulate our clocks to keep true sun time, because true sun time is variable in length. Clock time must be uniform and regular. True sun time is variable because we are moving around the sun at a variable speed. We move fastest when nearest the sun and slowest when farthest from it. Therefore, the true solar day —the time between the two successive passages of the true sun across our meridian*—varies in length from day to day. No clock can be adjusted to keep such time.

THE MEAN SUN

To get around this difficulty and still be able to use the sun as our timekeeper, the astronomer devised the mean solar day—our ordinary twenty-four hour day—which is the time that elapses between two successive passages of the mean, or imaginary sun, as it may be called, across the meridian. For convenience, we count this day from midnight to midnight, instead of from mean noon to mean noon.

It seems strange to keep time by a body that we cannot see and that, in fact, does not exist, but that is exactly what we do.

Our clocks are regulated to keep the mean or average sun time of the year, and the mean sun is the imaginary body that determines by its regular and uniform motion our mean solar day.

Sometimes the true sun—also called the apparent sun—is ahead of the mean sun in crossing the meridian; sometimes it is behind; sometimes the two bodies cross at the same time. There is never a difference of more than sixteen and a fraction minutes in the passage of these two bodies across the meridian. This difference in time between the passage of the true and the mean sun across the meridian is

*The meridian is a due north and south line passing through the observer's position and the north and south poles.

called the Equation of Time, and it is given in the almanacs for every day of the year. We can find out when the mean sun crosses the meridian by applying the Equation of Time to the time when the true sun crosses the meridian. So, though we cannot see the mean sun, we can always tell when it crosses our meridian. This time we call mean noon, which is noon by the clock.

Sidereal or star time

There is still another very important kind of time known as sidereal or star time.

The turning of the earth on its axis with respect to the sun or the time that elapses between two successive passages of the true sun across our meridian varies in length, because we are going around the sun at a non-uniform rate. But the turning of the earth on its axis with respect to a fixed point in the heavens or with respect to a star is uniform and unchanging in length. So far away are the stars that the motion of the earth in its orbit around the sun has no effect upon the length of the day that is determined by two successive passages of a star across the meridian, or the sidereal day, as it is called.

Clocks can be regulated to keep sidereal or star time, because it is uniform and unchanging. Such clocks are in common use at observatories and are known as sidereal clocks. By making suitable corrections to the time shown by the sidereal clock, we obtain the corresponding time for our mean solar or ordinary clocks.

The sidereal day is shorter than the ordinary or mean solar day by three minutes and fifty-six seconds, for it takes the earth just that much longer to turn around on its axis with respect to the mean sun than it does to make a rotation with respect to a star. It must be remembered that we are going around the sun, and that, during the day, we advance a certain distance in our orbit. So the sun moves, *apparently*, eastward a little every day, and the earth has to turn a little farther to get in line with it again. The time that it takes to turn this extra distance amounts to three minutes and fifty-six seconds daily. The stars are so distant that our motion around the sun makes no difference in star time, or the length of the sidereal day.

SIX-INCH TRANSIT TELESCOPE

Used at the U. S. Naval Observatory to observe the passage or "transit" of stars across the meridian. The time recorded when a star crosses the meridian gives the correction to the clocks that are used in sending out the time signals.

It follows from this that the stars will seem to come to the meridian three minutes and fifty-six seconds earlier each successive night. The sidereal day gains this much on the mean solar or ordinary day every twenty-four hours. In two weeks this gain amounts to about an hour and a star will come to the meridian an hour earlier than it did at the beginning of the two weeks. In 365 days, or a year, it amounts to one day.

Telling time by the stars

This gives us a way of correcting our watches by the stars. If you look at

your watch tonight as a certain star passes your meridian, and then again tomorrow night when the same star again crosses the meridian, you will find that it crosses three minutes and fifty-six seconds earlier by your watch on the second night. This is true if your watch has kept correct time. You can set it to the correct time by the star's passage across the meridian if it does not show this difference.

METROPOLITAN LIFE BUILDING
The largest tower clock in this country is on this building, which stands at Madison Square, New York City.

In the same way, but with a far greater degree of accuracy, the astronomers at the United States Naval Observatory observe the passages of the stars across the meridian with their transits, which are telescopes set in the meridian to observe the meridian passage of the stars. By these observations astronomers correct their clocks, and then, by radio and telegraph, broadcast the results to the whole country and to ships at sea, that all may set their clocks to the correct time with the aid of the stars.

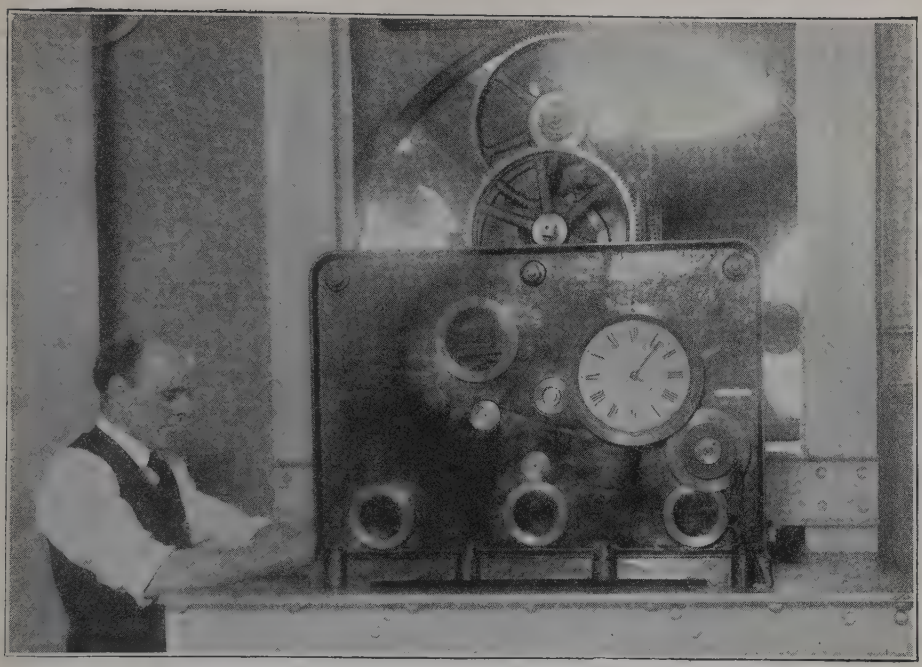
One may ask why we do not keep star time directly, since it is uniform and clocks may be regulated by it. The difficulty lies in the fact that the sidereal noon comes at all the different hours of the day and night in the course of the year, and, as we have said, we like to regulate our activities, approximately at least, by the rising and setting of the sun. Therefore we keep our mean solar or ordinary clock time for general use, leaving the sidereal clocks to the astronomers.

STANDARD TIME

You may ask, "What is Standard Time? Is not this the kind of time that our clocks keep?" That is indeed true in the United States. However, Standard Time is simply the mean solar time for certain meridians, and it is used for convenience and to avoid confusion, especially among travelers and in railroad schedules.

The sun rises earlier at places east of us and later at places west of us. If everyone kept local mean solar time, as determined by the passage of the mean sun across his own meridian, no two watches would show the same time, except in one place or when traveling due north or due south on one's own meridian. One would find himself continually setting forward or setting back his watch, when traveling even short distances east or west.

For the convenience of all, the country is divided into Standard Time belts and everyone in the same belt keeps the same time—that of the Standard Meridian for that belt. People in the Eastern Standard Time belt keep the time of the 75th meridian west of Greenwich, England. In the Central



DRIVING MECHANISM FOR METROPOLITAN CLOCK HANDS

This mechanism propels the gigantic hands of the Metropolitan clock pictured in the tower on the opposite page.

Standard Time belt the 90th meridian west of Greenwich is the Standard meridian and Central Standard Time is one hour earlier than Eastern Standard Time. In Denver we have Mountain Time, which is that of the 105th meridian, and on the Pacific coast we have Pacific Time, which is that of the 120th meridian. The time adopted in each belt is one hour earlier or later than that of the next adjacent time belt. It is earlier than the time of the belt next to it on the east and later than the time of the belt next to it on the west.

Famous Tower Clocks of Today

Probably the most famous tower clock in the world is the one on the Victoria Tower of the Houses of Parliament in London. The inscription reads: "This clock was made in the year of our Lord 1854 by Frederick Dent of the Strand and Royal Exchange, Clockmaker to the Queen, from the design of Edmund Beckett Denison, Q. C.*" The tower is 40 feet square and the four dials are each 23 feet across and 180 feet from the ground.

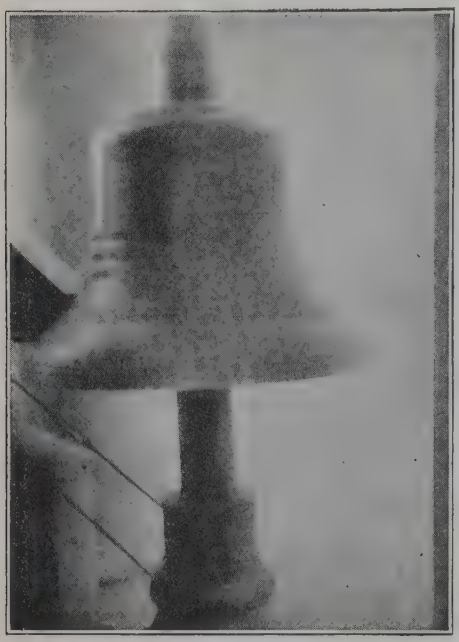
The hour is struck on Big Ben II, a giant bell weighing more than 13 tons and the clapper 766 pounds. The Westminster of Cambridge chimes are rung on four smaller bells.

In this country the largest tower clock is the one on the Metropolitan Life Building in New York City. It was completed in 1909. It is 346 feet above the sidewalk and its dials are 26 feet 6 inches in diameter. The minute hand measures 17 feet from end to end and weighs 1,000 pounds.

The hour is struck on a 7,000-pound bell with a hammer weighing 200 pounds. Chimes are struck on four bells, the largest weighing 7,000 pounds.

*Q. C. stands for Queen's Clockmaker.

The bells are mounted on pedestals between marble columns outside the 46th story of the building and are said to be twice as high as any other large bells in the world.



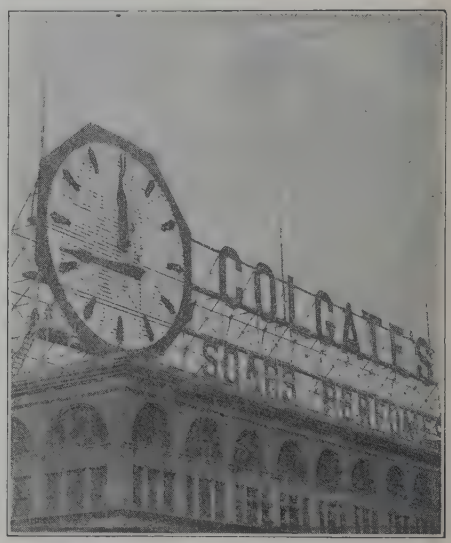
A 7,000-POUND BELL

One of the bells of the Metropolitan clock, located on the forty-sixth floor. Electric hammers with blows of 200 pounds impact strike the hours on this bell.

As darkness approaches the clock is brilliantly illuminated and at the same time an automatic switch lights up a great electric lantern, located at the top of the tower. Powerful electric flashlights, marking the hours in the evening, may be seen for a great distance, far beyond any possible transmission of sound. The time is signaled as follows:

Each of the quarter hours is flashed in red and the hours in white light. One red flash indicates the quarter, two red flashes the half, three red flashes the three-quarters and four red flashes the even hour. The four red flashes are followed by a number of white flashes indicating the hour. This clock is a model of accuracy and it seldom gains or loses more than one or two seconds a day. It is always set right as soon as it is a few seconds out.

The largest single face clock in this country is the advertising clock of Colgate and Company in Jersey City. The dial is 50 feet in diameter and the hands are 27¼ and 19½ feet long. Put up in 1906 this big timekeeper overlooks New York harbor and is a conspicuous mark on the long Jersey skyline.



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LARGEST CLOCK IN THE WORLD

The clock of Colgate and Company in Jersey City. The great open dial is fifty feet in diameter.

The oldest tower clock in New York City dates back to 1766. It is in the tower of St. Paul's Chapel where George Washington worshipped and where his pew is still to be seen with its memories of the first days of our Republic. Of recent years the old clock has shown the inroads of time and it no longer measures the passage of time accurately.

Book *of* Plants and Animals

The Range of Plant Life
Bacteria
Algae
Fungi
Mosses and Ferns
Wild Flowers
Weeds
Shade Trees
Insects
Some Other Invertebrates
Fishes
Amphibians
Reptiles
The Story of Birds
Familiar American Birds
Some Four-Footed Friends
Wild Animals at the Zoo

THE MAJESTY OF TREES

Royal palms with tall, slender trunks, topped with magnificent tufts of leaves. The great leaves, resembling hands, give the palm tree its name.

MUSHROOMS IN THEIR NATIVE HAUNTS
The morels, shown in this picture, are highly prized as an edible mushroom.

PLANTS AND ANIMALS

(AN INTRODUCTION)

THE simplest forms of plants are similar to the simplest forms of animals. The most important difference is in what and how they eat. A plant can manufacture its own carbohydrates, such as sugar and starch, and, with the addition of water and salts, can make increasingly complex proteids, ending in protoplasm, or living substance. An animal cannot make carbohydrates out of inorganic matter. The animal also requires ready-made proteids. Thus, a plant needs only simple food which it makes for itself while an animal demands complex food.

Both plants and animals move, are sensitive in varying degrees, feed, breathe, throw off waste matter, grow and reproduce. Plants commonly absorb their food materials through the outer surface; animals usually swallow or envelop theirs.

In 1801, Lamarck, a French student of animal life, gave the name *biology* (from two Greek words, meaning "life" and "discourse") to the study of living things, both plants and animals. Biology is divided into *botany* (from the Greek word for "plant"), which treats of plants, and *zoology* (from two Greek words, meaning "animal" and "discourse"), the science of animals. For practical purposes we usually exclude from biology the study of human beings. In this volume, the "Book of the Races" and the "Book of the Human House" cover the story of man.

The more elementary study of biology forms a large part of what is called *nature study*. The "Book of Earth and Sky" also deals with subjects that are included in nature study. In the modern school, or in any type of child education today, nature study

holds a prominent place. It trains the eye and the ear and makes observation in general the key to the secrets of the world in which we live. Thoughtfully pursued, especially with the aid of classification, nature study lays the foundation for all science study.

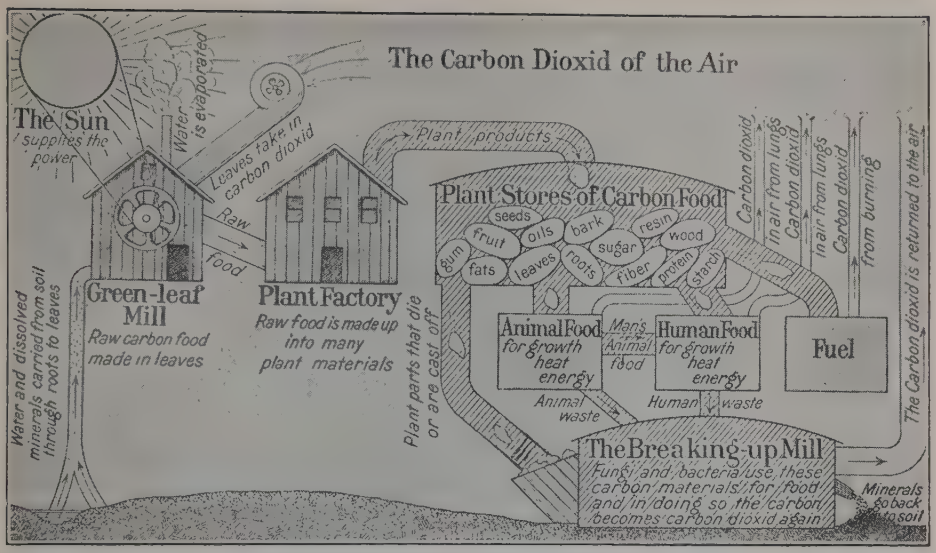
This "Book of Plants and Animals" reveals some of Mother Nature's many secrets. Beginning with plants we are introduced to the more important of the commonly met forms, from the microscopic bacteria to the towering elms of New England.

In the field of animal life there are two great divisions—those forms having no vertebral column, or backbone, and those supplied with one. As examples of the former, the invertebrates there are described many interesting invertebrates of the land and the sea. Insects are invertebrates of such importance that they are described in a separate article. The backboned animals, or vertebrates, are next treated. The amphibians, who lead a double life (on land or water), come first. Then follows the story of the reptiles. Birds, the great group of feathered animals, are discussed in one article, followed by another which tells many details about thirty-two of our common American birds. Some of the common mammals, which have been made pets, are discussed sympathetically by a naturalist. Finally the former director of the famous New York Zoological Park has told of the wild animals at the zoo, dwelling especially on the value of classification as an aid to an acquaintance with the many diverse animals of the earth.

In the following volume of this series, under the heading "Agriculture," the domestic animals such as the horse, cow, pig and sheep are discussed. Likewise, in the same section, the important farm plants, such as corn, cotton and wheat are described. In fact, in many of the pages of the following volume you may read more about various plants and animals, especially in their relation to man and his needs. (See "Meat Packing," "Fur," "Fishing" and other articles.)

BIOLOGY CLASS AT THE ZOO

A biology class from a New York high school visiting the Reptile House at the New York Zoological Park.



THE CARBON MILLS AND PLANT LIFE

This diagram shows the "carbon cycle," or the processes through which carbon is constantly passing. Beginning at the upper left-hand corner, carbon is taken from the carbon dioxid supply of the air and, by the energy of sunlight in the leaves of green plants, converted into solid materials that serve as plant stores, as food for both plants and animals, and as fuel; then by the breaking-up process of this material, the carbon is returned to the air. (By permission, from McCubbins *Fungi and Human Affairs*, World Book Co., Yonkers, N. Y. [1924]).

THE STORY OF PLANTS*

THE RANGE OF PLANT LIFE

EVERYBODY knows that there are lower animals like fishes, frogs and toads and higher animals of which man is the supreme example, but how many of us realize that the plant world is likewise separated into the lower forms and the higher? Indeed, on one end of the scale occur living things so minute in size and low in form that it is impossible to state with certainty whether they are plants or animals.

From these lowest and smallest of living things to the higher plants such as asters, goldenrods and other wild flowers, weeds, and large flowering trees, there is a gradual development from simple plants without roots, stems, leaves or flowers to species with such complicated and intricate structures as may be found when you examine the flower of a dandelion. You will then discover that what is ordinarily called a dandelion flower is really a mass of tiny blossoms gathered together into a head. The study of the development of plant life from the low, simple forms to the higher, complex species is both fascinating and instructive. At the bottom of the scale of life are the bacteria and microscopic algae, some of which are claimed alike by the botanist and the zoologist, for no one knows whether they are plants or animals.

In the following pages are introduced, in order, the bacteria, the algae, the fungi, the mosses, the ferns, the wild flowers, the weeds and the trees.

*Common names of plants are in accordance with *Standardized Plant Names*, published by the American Joint Committee on Horticultural Nomenclature, 1923. In some instances additional commonly used names, not authorized by the Committee, have been included.

BACTERIA

GERMS, microbes, bacteria—what are they? Simplest and smallest of living things—a full-sized bacterium consists of but a single tiny cell that has more room in a drop of water than you would have in the Great Salt Lake—they are among the most useful as well as the most destructive forms of life. They

BENEFICIAL BACTERIA

These nodules on the root of soy bean are caused by nitrogen-gathering bacteria.

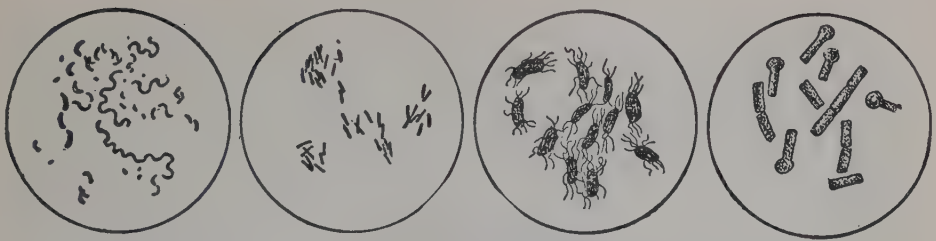
are useful because they cause decay; destructive since they are held responsible for pneumonia, typhoid fever and many other diseases, and for the spoilage of vast quantities of food products. In spite of their harmfulness, however, the world could not long exist without bacteria. Imagine what would happen were it not for decay! The face of the earth would soon become so littered with the remains of plants and animals that there would be no room for the rest of us.

One of the interesting things about bacteria is the manner in which they reproduce. This is done in the simplest fashion imaginable, because when the single cell of an adult bacterium is ready to reproduce, it merely divides into two parts, each of which is in turn a bacterium that reproduces in the same manner. Since the process requires but a few minutes, it can readily be seen that a single bacterium soon forms a very large family. It has been estimated that if a single bacterium is given all the food and other things necessary, in three days it can form a mass weighing a ton and this mass can double in weight every hour or two.

Have you ever wondered what bacteria actually look like? Many of them are simply little round cells, but others resemble tiny sausages in shape and some are spiral or rod-like in form. Most bacteria possess minute hairs with which they swim in a very efficient manner.

One of the important and interesting functions performed by bacteria is known as fermentation. This simply means that sugar solutions are attacked by bacteria and changed into other forms, acids being a usual product. For example, if milk is allowed to stand too long, the bacteria attack the sugar in the milk and the milk becomes sour. The sour taste is due to the formation of acid since all acids taste sour. A similar thing happens when sweet cider is changed first to alcohol by yeast and then to sour vinegar by bacteria. The "mother" of vinegar that may sometimes be seen when vinegar is spoiling is nothing in the world but colonies made up of millions of bacteria.

Bacteria are everywhere, floating on dust particles in the air, living in the soil, in water and in the bodies of plants and animals. The kinds that cause

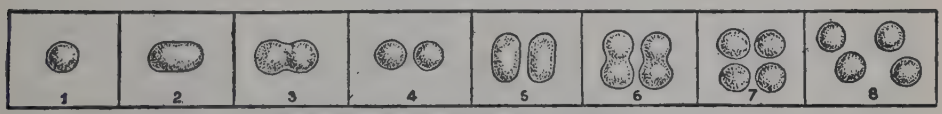


HARMFUL BACTERIA

Some enemy bacteria, shown a thousand times bigger then they really are. In the first circle are the bacteria that cause cholera; those in the second cause tuberculosis; the third, typhoid fever, and the last cause lockjaw.

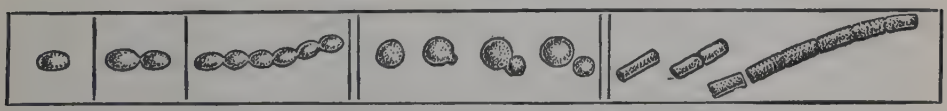
HELPFUL BACTERIA

These friendly bacteria are also shown magnified a thousand times. The small ones in the first circle make milk sour, while the larger ones help make butter and cream; those in the second circle are found in yeast and help make alcohol; in the third are those that make vinegar, and in the fourth are bacteria that help to make cheese.



FROM ONE BACTERIUM TO FOUR

The growth shown here takes place within an hour's time.



HOW BACTERIA ARE BORN IN A FEW MINUTES

This and the row of drawings above show how bacteria grow. Some form a "waist" and either break off or add others. Others form buds which break off. Others form into long rods and break off into separate bacteria afterwards. In twenty-four hours, if they all lived, the children of one bacterium would form a line reaching from end to end of Illinois, but if the bacteria were as big as shown here this line would be long enough to go twenty times around the earth.

infection of wounds are very common and it is for this reason that cuts and burns should be treated with iodine or some other means of killing the bacteria and then kept clean to prevent infection.

Among the most interesting of the useful bacteria are those that live on the roots of clover, alfalfa and bean plants where they cause the formation of little nodules that are simply very small bacterial tenement houses. Curiously, in return for their lodging, they are busy gathering from the air nitrogen fertilizer which is used by the plants upon which they live. Plants must have nitrogen in order to grow but they do not have the ability to use the abundant supply contained in the air.

BACTERIAL ENEMIES THAT STEAL HEALTH

This drawing shows in highly magnified form what happens in a drop of blood when we are battling with typhoid fever. The little black invaders are typhoid bacteria. The white cells repel the attack. If they succeed in devouring the bacteria, we live; if the white cells are unsuccessful, we die.

ALGAE

HAVE you ever noticed the greenish slime that accumulates in watering troughs, stagnant water and even in flowing streams? Put some of this slime, called pond scum, under a microscope and you will be amazed to see that it is made up of living cells—in fact, the lowly slime is an accumulation of tiny plants, many of which are exceedingly handsome.

Most of the pond scums, or algae, as they are called, are quite harmless but occasionally undesirable forms get into reservoirs of drinking water and impart bad flavors and odors to the water. They can readily be destroyed and the water made sweet, however, by dragging a bag of powdered copper sulphate, or bluestone, through the foul water, since the tiny plants are easily killed by a quantity of bluestone so minute as to be harmless to human beings.

The Kelps of the Pacific and the Sargasso Sea of the Atlantic

The algae, of which the pond scums are a part, vary in size from one-celled plants so small that a high-powered microscope is necessary to detect them, to the huge kelps of the Pacific Ocean, some of which are several hundred feet in length and are among the largest of living things. The giant kelps have recently been utilized in the production of valuable fertilizers. The famed Sargasso Sea, about which a myth exists to the effect that it captures and holds ships, is a floating mass of kelp-like plants somewhere in the Atlantic Ocean. Although it impedes the progress of ships, as Columbus discovered on one of his voyages, the idea that it holds great numbers of deserted ships as captives is merely a romantic legend.

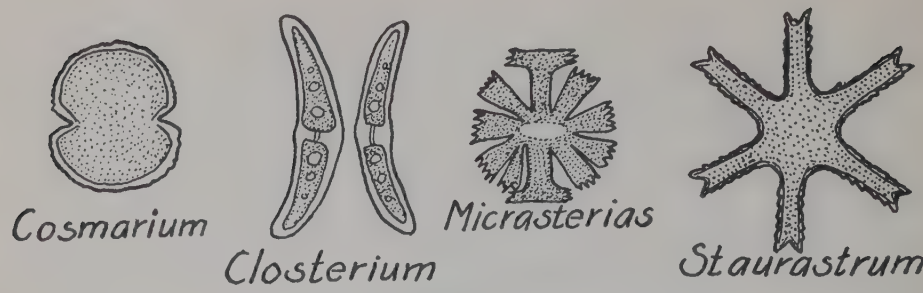
Some Interesting Red Algae

In addition to the great variation in size, the thousands of species that comprise the algae show marked differences in color, ranging from green to brown, violet and red. The strange red or "bloody snow" described by Arctic explorers is really a collection of millions of tiny red algae, plants that thrive on the snow crust. The coloration of the Red Sea is likewise due to red algae. Some of the much larger branching red algae growing on the sea bottom and attached to rocks make graceful filaments of lace-like design. One of the pleasures of a visit to the Pacific coast is to view these

U. S. Bur. of Soils Photo

KELP

Unloading kelp, giant algae used in the manufacture of potash.



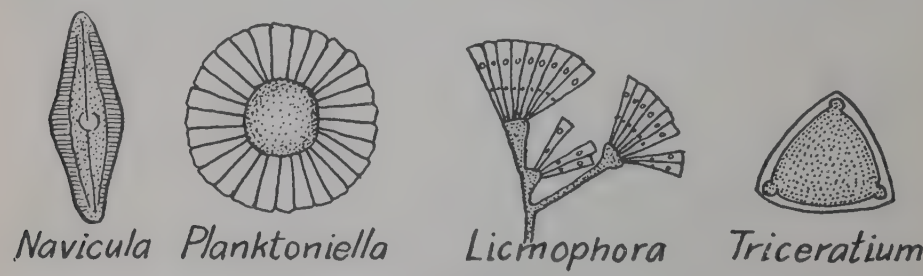
DESMIDS

These beautiful little one-celled algae are often handsomely ornamented with delicate markings. Four species are illustrated here.

beautiful plants through a glass-bottomed boat, as may be done at Catalina Island, California, where vivid red algae grow in profusion.

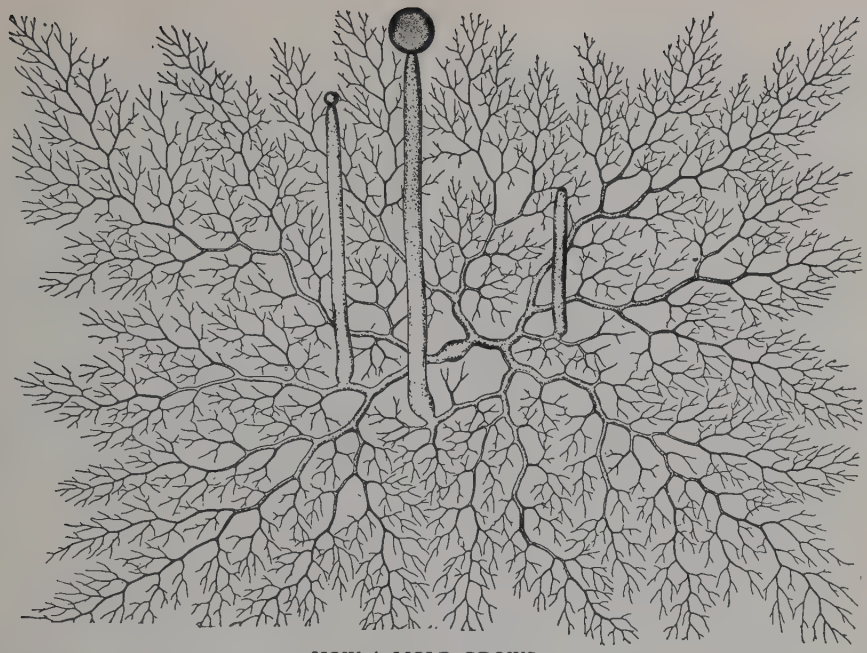
THE DESMIDS AND THEIR RELATIVES, THE DIATOMS

Mention should be made of the desmids, tiny one-celled algae that live along the margins and on the bottom of fresh-water ponds, lakes and streams. These cells are beautiful in form and remarkably symmetrical, resembling half-moons, snowflakes, dumb-bells, and so on. Closely related to the curious little desmids are the equally interesting diatoms, a strange group of several thousand species most of which are one-celled and able to glide about in the water. They form a large part of the plankton, or floating plant and animal life on the ocean. In reality these diatoms provide a vast pasture on which graze small ocean animals, which in turn form food for fishes. Each little diatom is covered with two shells that fit together like a pill box and when they die the accumulation of shells on the bottom eventually forms a type of earth that is used in making polishing powders and was, at one time, widely utilized in the manufacturing of dynamite. The city of Richmond, Virginia, is built on a deposit of these tiny diatom shells several feet in thickness. These shells are seen under the microscope to have the most varied and beautiful surface markings, by which one form may be distinguished from another.



DIATOMS

These tiny plants are found in both fresh and salt water and also on damp soil. They form a large part of the plankton, the free-swimming plant and animal life on the surface of the sea. The author has sketched four species of diatoms.



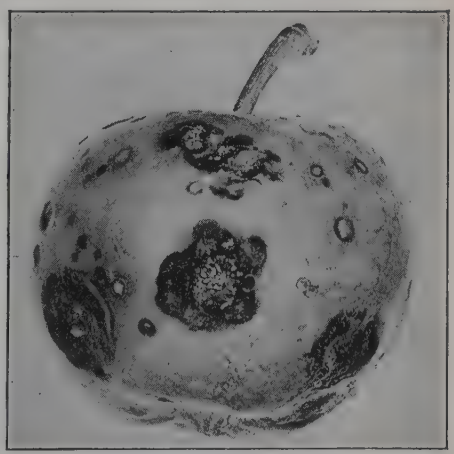
HOW A MOLD GROWS

Fungi are really little plants of microscopic structure. This drawing of a common mold (*Mucor muceda*) shows the character of the plant. Note the structures in the center, the tops of which contain the spores.

FUNGI

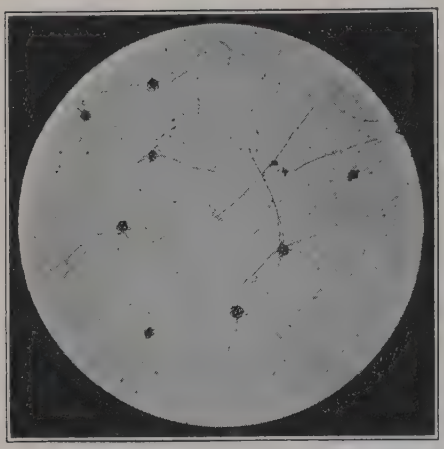
PUT an old pair of shoes away in a damp closet and in a few weeks they will be covered with a greenish, yellowish or white mold. Forget to air out the bread box and the stale bread becomes brown, black or green with mold. Do you suspect that these molds and mildews are minute plants that are closely related to mushrooms and toadstools and to other forms that live on trees and crop plants and cause destructive diseases of the plants upon which they live?

What are these fungi, anyway? You have already learned that the green coloring matter found in leaves enables green plants to make their own food and so work for their living and lead independent lives. But there are shirkers in the plant world just as there are in the human family and so there has developed a large group of lazy plants that refused to work for their living. As a consequence they lost their green coloring matter, or chlorophyll, their badge of independence. Now they are unable to earn

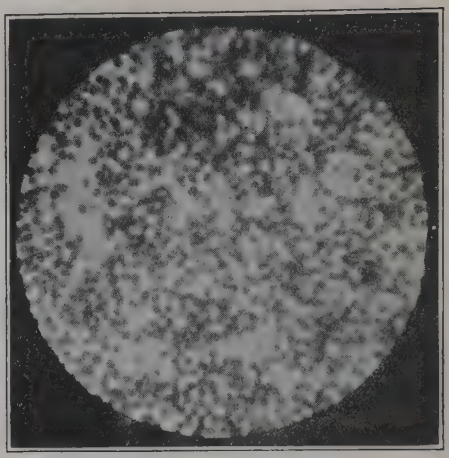


BITTER ROT OF APPLE

This serious disease of apples in warm climates is caused by a fungus.



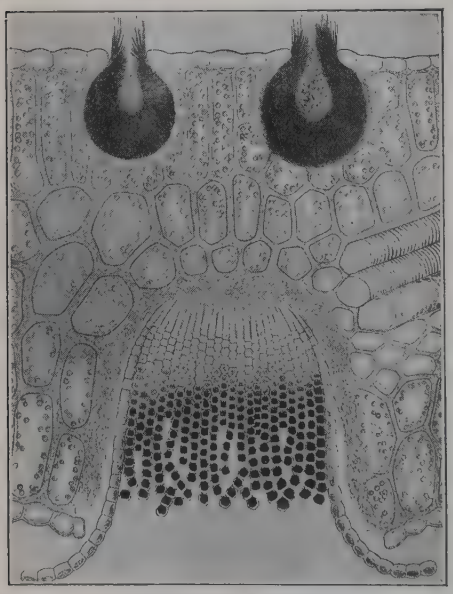
Spores that have been scraped from the diseased spot on the leaf. (Highly magnified.)



The same spores germinating to form new fungus plants will in turn form spores.

THE FUNGUS THAT CAUSES THE LEAF SPOT OF CUCUMBER

their own living, so they must steal their food either from other plants, as in the case of the numerous fungi that cause plant diseases, or else they live upon dead things, as with mushrooms that live on decaying matter in the soil or the bracket fungi on dead trees. The fungi that live on dead things, however, perform a very useful function since they promote decay in a similar manner to bacteria and so help the world to get rid of large quantities of useless dead material.



A DESTRUCTIVE FUNGUS

Cross section of barberry leaf, showing how spores of barberry rust are formed. These spores blow to wheat, sometimes ruining the crop. Without the barberry this destructive fungus causes practically no damage.

Most of the fungi reproduce by means of spores, tiny structures that frequently blow about in the wind, and act much like the seeds of higher plants. The molds on old shoes and on stale bread, for instance, get their start by means of tiny spores that float in the air. A spore germinates and the young fungus may gain entrance to a leaf or stem through the breathing pores, a wound, or by boring directly in. Once it has started growth in the green plant, the fungus may cause so destructive a disease as potato blight, the malady that caused the terrible famine in Ireland due to the failure of the potato crop. The lack of potatoes, in turn, was responsible for the heavy emigration of the Irish people from Ireland to America. The black stem rust of wheat is

another fungous disease that causes a loss of millions of dollars every year.

In addition to promoting decay, a number of fungi, principally the mushrooms and truffles, are valuable as food products. Truffles are really mushrooms that grow in connection with the roots of trees. In France and Italy pigs and dogs are trained to detect the presence of truffles by the sense of smell. One of the molds that is similar to the common green mold is used in flavoring Roquefort cheese.

Among the most useful of the fungi are the yeasts, which are single-celled plants of microscopic size, although much larger than bacteria. In common with bacteria, yeasts exist almost everywhere. They are valuable since they cause fermentation, a process used in the making of sauerkraut and in the baking of bread. Although wild yeasts fly around on dust particles, bakers use special strains that are cultivated for this purpose.

Some of the mushrooms are exceedingly poisonous. The only safe rule to follow is to pick only such easily recognizable edible species as the puffballs, the inky mushrooms, the beefsteak fungus and the morel.

CORN SMUT

This common fungus does great damage to corn. In the young, succulent stage the smut can be eaten like mushrooms.

Courtesy Nature Magazine

RODMAN'S MUSHROOM

A short, thick, solid, fleshy mushroom commonly grown for the market. When cut, this fungus has an agreeable nutty flavor.

BRINGING HOME THE PEAT
A scene in the back country districts of Ireland. Peat is the product of dead moss.

MOSSES AND FERNS

FROM the simple rootless, stemless, leafless algae and their backward relatives, the fungi, we are now ready to step up a rung on the ladder of plant life to the mosses with their green leaves and distinct stems.

Mosses and their service to man

Of particular interest are the sphagnum or bog mosses, inhabitants of bogs and moors. The bog waters in which they live are so sour that bacteria cannot thrive in them, consequently there is little decay. Almost perfect specimens of prehistoric animals and men and even clothing have been recovered from sphagnum bogs. Occasionally the moss, with other vegetation, covers a body of water like a heavy layer of ice on a pond. This is the condition that causes quaking bogs, so called on account of the wave-like motion created when trod upon. As the dead moss accumulates, it gradually compresses and is changed into a material known as peat that may be cut into blocks and burned. Peat is an important source of fuel in Europe, and will probably some day be more widely used in America. Sphagnum moss is also used in paper making. During the World War the dried sphagnum was found to be unexcelled as an absorbent for dressing wounds. It is also much used by nurserymen and gardeners for packing around plants to be shipped.

The common mosses of lawns, woods and fields are the plants usually referred to as true mosses. The little capsules on the ends of the thread-like stems contain the spores by means of which the mosses multiply.

The house fern and its relatives

The next step in the development of the higher forms of plant life is represented by the ferns. Although the average person is familiar only

with house ferns and perhaps one or two woodland species, as a matter of fact there are in the world over three thousand different kinds of ferns some of which are climbing plants while others are trees that grow to fifty feet.

In the common house fern the little dark spots on the under surfaces of the leaves, frequently mistaken for bugs or some form of disease, are really small patches of spores by means of which little ferns get a start, although this method is too slow for the florist who makes several ferns out of one simply by dividing the root.

Among the close relatives of our familiar ferns is the resurrectionplant of Texas and Mexico. This curious plant has the ability to coil up into a tight brown ball during the dry period. In this condition the plant appears to be dead, but as soon as rain falls the leaves unroll, the green color returns and it is very much alive.

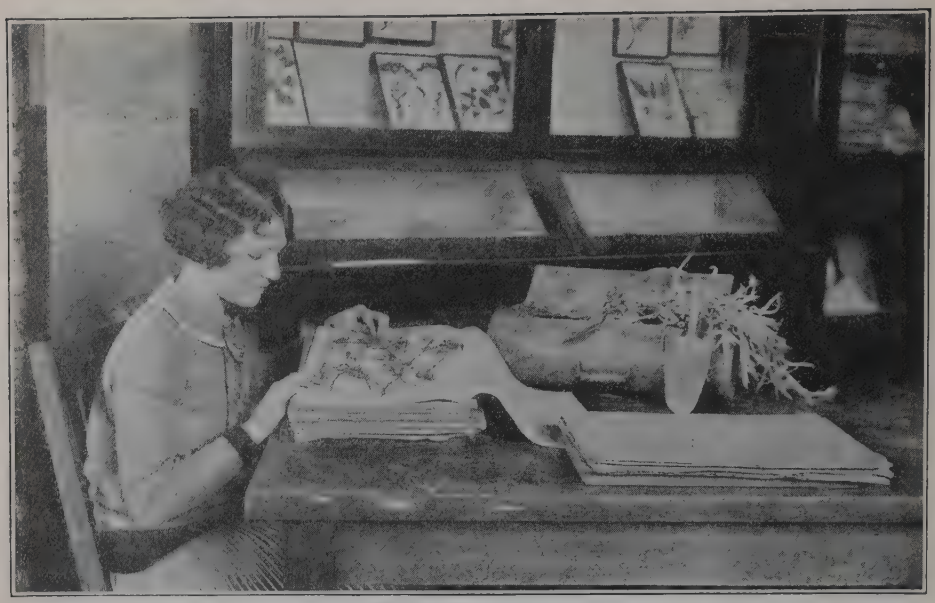
We have now seen something of the lower and higher flowerless plants from the algae of simple structure to the more complex ferns. We are now ready to consider the highest types of plant life, the weeds and wild flowers and the trees.

SPLEENWORT

This common wood fern (*Asplenium trichomanes*) is marked by its purple stem.

A COMMON WOOD FERN

Found in rich forest territory from Canada to the Mason and Dixon Line. Its scientific name is *Aspidium Spinulosum*.



HERBARIUM MAKING

This is the way specimens of plants are placed between newspapers and piled between blotters ready to be pressed. Mounted specimens are seen in the cases on the wall.

WILD FLOWERS

AN acquaintance with the various kinds of plants that grow in fields, gardens and forests is a lifelong joy. Even in later years when the hurly-burly of business confuses and tires the brain, a stroll into the open country to meet old friends among the wild plants is frequently far more soothing, restful and beneficial than all the medicine the most skillful doctor can prescribe. Mother Nature holds many interesting secrets awaiting those who care to inquire.

Studying plant life is a fascinating subject, but in order to secure the greatest benefits it should be done in a systematic rather than a haphazard manner. One of the best ways to unravel the secrets of nature in an orderly fashion is to start a herbarium.

How to make a herbarium

What is a herbarium? Although the word is rather imposing, a herbarium is simply a collection of dried plants. The simplest form of herbarium is a notebook such as is commonly used in schools, in which flowers, leaves and other plant parts have been dried between the pages and mounted with glue. The addition of short notes regarding the place and date of collection and the names of the species usually completes this simple type of herbarium. A small notebook herbarium of this character is better than none at all since it is very helpful as an aid to remembering the plants. Usually, however, preserving plants on even so simple a scale is so interesting that it creates a desire for a better system.

An excellent herbarium can be made by mounting each plant on a separate sheet of paper, the standard size sheet measuring 16½ by 11½ inches. For small collections, half-size sheets are satisfactory. By preserving the specimens on separate sheets, the plants

can be filed in related groups in harmony with the plan used in any standard book on botany.

Before mounting, the specimens should first be pressed and dried. This is done by placing each plant neatly between sheets of folded paper such as newspaper and between these is placed blotting paper, carpet paper or any other soft, porous type that absorbs moisture readily. Several thicknesses of newspapers are satisfactory for ordinary specimens. The sheets containing the plants are then placed in a pile, a board is put on top of the stack and several bricks or other heavy objects are placed on top of the board. This simple arrangement makes a perfectly satisfactory home-made plant press from which the specimens will emerge in excellent shape after a few days. It will be necessary, however, to change the absorbent papers daily to prevent the accumulation of moisture, molds and mildews.

When the specimens are crisp and dry they are ready for mounting. In mounting, main reliance should be placed on ordinary glue, although for fleshy plant parts narrow strips of adhesive tape are very helpful. The label should then be placed in the

HOME-MADE PLANT PRESS

This very satisfactory press for plant specimens requires only a board and three bricks.

COLLECTING SPECIMENS

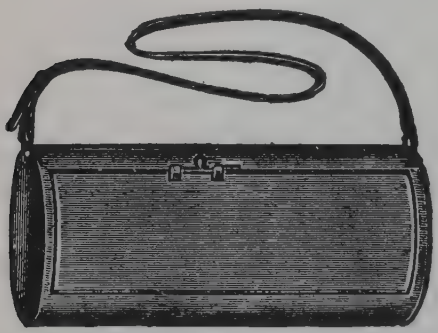
A plant has been dug out by the roots. It will be placed in the shoe box to be pressed and dried later.

lower right hand corner of the sheet. A careful collector will include the following data and arrangement:

COMMON NAME OF PLANT
Technical Name of Plant
Name of Collector — Where Collected. Date of Collection. Notes on Abundance, Environment, etc.

For example, let us suppose that Joe Harris and Bob Jones go on a field trip and collect a specimen of Canada Thistle. The label will then read:

CANADA THISTLE
Cirsium arvense Scop.
Joe Harris, Bob Jones — Near Lafayette, Indiana. July 24, 1927. In cornfield. Common in vicinity.

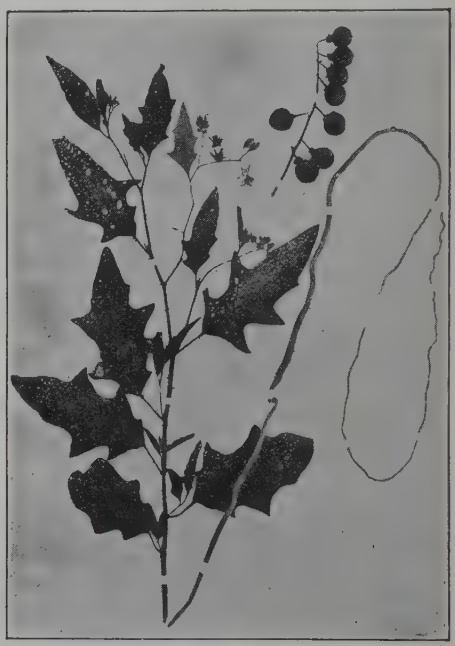


COLLECTING CAN
With this can slung over his shoulder, the botanist starts on his specimen collecting trip.

A FEW SUGGESTIONS

Some students are careful plant collectors, others are exceedingly careless, with no regard for the rights of others. People who have made a study of plants have noted that our flora is undergoing a gradual change in which the handsomest species with gaudy flowers are gradually being replaced by inconspicuous and otherwise less appealing plants. Indeed, over large areas such wonderful wild flowers as arbutus, ladyslipper, fringed gentian and dogwood have entirely disappeared, probably forever.

There are a number of reasons for this change some of which, such as grazing, cultivation and lumbering, are unavoidable. One of the strongest reasons for this undesirable change, however, is the careless, ruthless pickers of plants who gather the most attractive flowers in huge armfuls and basketfuls, to be cast aside as soon as they wilt. These persons do not realize that the purpose of flowers is to produce seed and that without flowers the plants cannot multiply.



READY FOR THE HERBARIUM
A specimen of bull nettle (Solanum Carolinense) correctly mounted for the herbarium.

Dogwood, laurel, redbud and a multitude of other beautiful species have practically disappeared in the vicinity of our cities. The recent remarkable

increase in the number of automobiles has also brought the country closer to the city, with increased danger to the attractive wild plants. It is with the idea of assisting in the preservation of the natural beauty of our flora that the following suggestions are offered:

(1) Always leave enough flowers to form a seed crop that will perpetuate the species.

(2) Do not disturb the underground parts of Solomonseal and other plants that are comparatively rare.

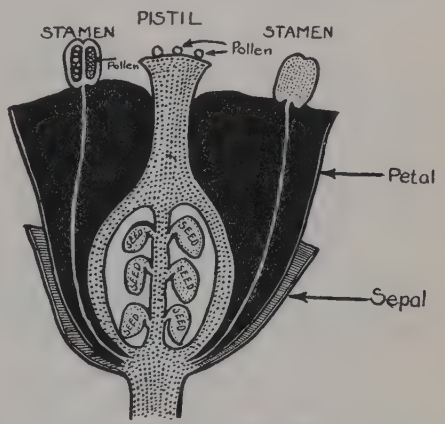
(3) Do not tear off branches of dogwood, redbud, and other shrubs in such a manner as to strip the bark and permit the entrance of fungi that will eventually kill the plants. Leave them for the next person to admire. Remember all your rights and where the next person's begin.

(4) Refuse to patronize street vendors and florists who offer arbutus, mountain-laurel, fringed gentian and other rare wild flowers for sale.

A FEW NAMES THAT WE NEED TO KNOW

What is a flower? This sounds like a perfectly simple question but even a trained botanist will have difficulty in giving a correct answer on account of the great differences shown by flowers of various kinds of plants.

An ideal flower, one that has practically all the floral parts with which we are familiar, has a pistil in the center, surrounded by stamens, petals and sepals. The *pistil* is commonly a bottle-shaped structure the tip of which usually becomes sticky. It is called a pistil on account of its resemblance to a pestle, the little pounder with which druggists grind and mix their drugs. Next to the pistil are the *stamens*, long, slender structures with swollen tips that are filled with the yellow, dust-like *pollen* grains. These pollen grains are carried to the sticky tips of the pistils by such means as bees, butterflies, humming birds or the wind. A few days after the pollen grains get caught on the sticky pistil tips, tiny baby plants or seeds begin



PARTS OF A FLOWER

Diagram of section of a typical flower, showing the parts. The pollen grains on the top of the pistil were deposited by insects.

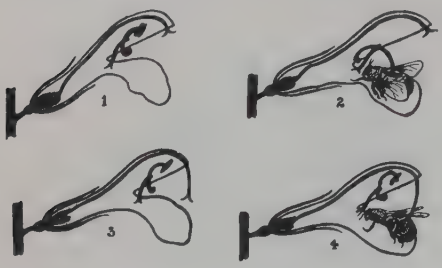
to form in the base of the pistil, but seeds cannot develop unless pollen has been caught on the pistil tip. The only really important parts of the flower are the stamens and pistils, which are necessary to form seed, but the most

HOW THE PRIMROSE IS POLLINATED

The primrose has two kinds of flowers. The nectaries are at the base of the pistil. When dusted on a bee, the pollen from the short stamens will pollinate the short pistils on another blossom and the pollen from the long stamens will pollinate long pistils.

attractive feature of a flower is the row of *petals* that surrounds the stamens and pistil. They are usually brightly colored in order to attract insects to assist in carrying the pollen grains from the stamens to the pistils, an act called *pollination*. Outside the pretty petals

are the green leaf-like structures called *sepals*, the main purpose of which is to protect the rest of the flower, particularly while it is tightly coiled into a bud.



CROSS POLLINATION IN GARDEN SAGE
After the pollen is dusted on a bee's back, the pistil elongates and becomes receptive.

Not all flowers, however, are fortunate enough to possess pistil, stamens, petals and sepals. The willow flower, for instance, consists merely of a tiny scale on which either a pistil or a pair of stamens is located. Next time you collect pussy willows, tear

FLOWER OF WILLOW
Each flower consists of a scale upon which either a pistil or a pair of stamens is located. They occur in catkins, or "pussies."

open one of the "pussies" and examine closely and you will be able to find these modest little flowers. Even stranger than this is the case of the self-fertile flowers found at the bases of violets and a number of other plants. These flowers never open; instead the stamens are pushed so tightly against the pistil tip that it is not necessary for bees or butterflies to help in pollination. This breaks a rule of nature that the pollen produced on a flower should be carried to the pistil of a flower of the same species growing on another plant. Botanists seem to like big names, and so they say that self-fertile blossoms are *cleistogamous*, when the petals remain closed during fertilization.

There is one other big name that we should know, because it is one of the most important words in the entire plant kingdom. It is *chlorophyll* and refers to the green coloring matter in plants. Indeed, so important is this green material that without it the world would soon be a barren waste upon which no human being could live. It is by means of this green coloring matter that plants are able to utilize the rays of the sun to combine water from the soil with a gas from the air into solid food matter. Most of this work is done in the leaves, which are the only real food factories in the world. It is upon this process that mankind is dependent for food, which may be eaten directly as when we eat lettuce, or indirectly as when we eat meat. (See diagram, Page 119).

INTERESTING FACTS ABOUT OUR COMMON WILD FLOWERS

In describing plants or animals the use of two Latin names, following the common English name, may seem unnecessary, but this practice is often helpful to students. Latin is a dead language and the Latin name is the same in every country. We have a common name for a plant or animal in one part of the country, and in another part we probably have an entirely different name. Then, in

England, France and Germany, there will be at least three other names. The first of the two Latin names tells the general group, or *genus*, while the second name gives the definite or specific group, or *species*, to which the plant or animal belongs, thus, "JACK-IN-THE-PULPIT (*Arisaema triphyllum*)." Sometimes we describe a plant, as the trillium, where a number of species are included in the same description. We then use the genus name but follow it with *spp.*, the abbreviation for species, thus, *Trillium* spp.

NEW ENGLAND ASTER

In spite of its local name this flower is distributed from Massachusetts, northern New York and Minnesota southward to the Gulf of Mexico.

ANEMONELLA (*Anemonella thalictroides*), sometimes called rue anemone, can be distinguished from the wood anemone by the untoothed, three-lobed leaves, since the leaves of the wood anemone are larger, toothed and five-parted. The blossoms are white, resembling the flowers of its namesake with which it is frequently associated.

ASTER (*Aster* spp.) From early spring until late fall there is a constant succession of flowers that begins with such a species as arbutus, hepatica and anemone and stops with a colorful display of asters and goldenrods.

Nature was in a bountiful mood when she distributed species of asters, of which more than 200 exist in

BLOODROOT

Fragile flowers, here today and gone tomorrow. When wounded in any part there is a flow of orange-red juice.

America. They are for the most part delightful wild flowers that vary in color from white to purple and blue, although occasionally they lose their charm when they invade fields and pastures, much to the annoyance of farmers.

BLOODROOT (*Sanguinaria canadensis*) is a woodland species that blooms during early spring. All parts of this attractive plant, particularly the fleshy root, give out a dark red, bloody juice on the slightest injury—a juice that furnished war paint for the Indians and a cough and cold remedy for our grandmothers. Unlike most forest wild flowers, bloodroot can readily be transplanted into a shady nook in the garden.

BLUE-EYED-GRASS (*Sisyrinchium* spp.), in spite of its narrow leaves and grass-like appearance, is really not a grass at all but a member of the iris family as a study of the flower structure will reveal. Plants are not classified by their vegetative appearance but by the structure of their flowers, or reproductive parts.

BLUEFLAG IRIS (*Iris versicolor*), often known simply as blueflag, is an

inhabitant of wet land where it sometimes takes such complete possession as to be regarded as a weed. Be that as it may, the strikingly handsome blossoms of this "flower of chivalry"

CARDINALFLOWER

A richer red than the bird which shares the name, the cardinalflower tells all the world its title.

are regarded by many admirers as the finest members of our wild flora.

The odd shape of the iris bloom is designed to insure cross-pollination through the agency of bees.

BOUNCING-BET (*Saponaria officinalis*) with its showy clusters of white to pink blossoms brightens up many an otherwise dull roadside and railroad right of way during midsummer. The plant is also called soapwort since the broken leaves with water form an excellent lather that was used by our colonial forefathers for cleaning fine silks and laces. The creeping roots are exceedingly persistent and the species should not be grown in gardens where it is likely to be a trouble maker.

BUTTERCUP (*Ranunculus* spp.), used by children to test one's liking for butter, thrives in meadows and pastures. The stems and leaves are exceedingly bitter and may cause sores in the mouth when chewed, or blisters on the hands when picked.

CARDINALFLOWER (*Lobelia cardinalis*), among the most vivid of our wild plants, derives its name from the gay color, similar in shade to a cardinal's hat. On account of its rare beauty and brilliant hue, the cardinalflower is eagerly picked and in common with its feathered namesake, the cardinal bird, is becoming almost extinct in the wild state. Fortunately, the cardinalflower is of easy cultivation and the colorful plant now enlivens many a picturesque garden.

CATCHFLY (*Silene* spp.) The handsome native species are notable for their sticky stems that sometimes catch ants and other insects intent on robbing the flowers of nectar and pollen. The unfortunate victims perish miserably, like flies on fly paper.

CATTAIL (*Typha* spp.) is one of our most familiar swamp plants. It grows from a heavy creeping root that was dried and ground by the Iroquois Indians into a sweet-tasting flour from which excellent bread and puddings were made. Cattail flour resembles rice flour in composition. It was used as a source of food in Germany during the World War. The roots also yield a sweet syrup that was widely used by the Indians. The yellowish spike above the brown cylinder on a cattail holds the pollen grains, which have been used also in the making of bread. Floss from the brown spikes even yields a cotton substitute and is of value for stuffing pillows and cushions.

COLUMBINE (*Aquilegia* spp.) is a denizen of rocky spots in open woods. Beautiful of flower and handsome of foliage, columbine has been prominently mentioned for honors as a national floral emblem. The United

States stands almost alone among the larger nations in being without a recognized plant emblem such as the thistle of Scotland, the rose of England, the fleur-de-lis (iris) of France, the shamrock of Ireland and the maple leaf of Canada. One species of the columbine is the state flower of Colorado.

The tips of the spurs of the columbine blossoms contain nectar that is eagerly sought by pollinating butterflies and moths and by robbing bees that cut through the petals.

CREEPING OXALIS (*Oxalis corniculata*), often called yellow sorrel or sour grass, is frequently mistaken for a clover on account of the shape of the leaves, although the plant is not even remotely related to clover. The leaves possess a pleasant sour taste that is very refreshing when the foliage is chewed on a warm day. They are also used as a garnishing. When cows eat the yellow sorrel (or its white or pink relatives) in liberal quantities, the milk is likely to become bluish and watery.

DAISY (*Chrysanthemum leucanthemum*), in spite of its long scientific name, is a modest and attractive species that has been adopted as the official floral emblem of the American Legion. The common name is really

BLUE COLUMBINE

The state flower of Colorado. There are also red, white and yellow columbines.

AMONG THE DAISIES

Though often regarded as a weed, the common daisy is a handsome flower, "Clear and simple in white and gold."

a misnomer since the flowers do not open in the morning and close in the evening as the true English "day's eye" does.

DUTCHMANS-BREECHES

Dainty blossoms hang tremblingly on stems that rise from the rich leaf mold of rocky forests, the preferred home of this wild flower.

The common daisy is a European plant that has made itself so thoroughly at home in America as to have become one of our bad pasture weeds. The sentimentally inclined still pull daisy petals, as they did in Shakespeare's time, to learn if their ideal "loves me or loves me not."

DUTCHMANS-BREECHES (*Dicentra cucullaria*), so called on account of the pantaloon-like shape of the two-spurred white blossoms, grows from scaly bulbs in the leaf mold of open woods. Both the tops and bulbs are poisonous to cattle and horses, causing a disease known as "staggers," particularly when grazing animals are turned into the woods too early when there is little else to eat. The nectaries (the parts of the flowers that contain nectar) are located in the spurs of the blossoms.

FLOWERING DOGWOOD (*Cornus florida*) presents a striking sight while in full flower during the spring. New England farmers believe that the opening of dogwood blossoms is the sign for planting corn. The bright red berries that follow the flowers furnish fare for many a hungry bird.

The most serious enemy of dogwood is the automobile. We frequently see automobiles coming to town loaded with great heaps of dogwood intended for decorating store windows, dwellings and even churches. There is practically no dogwood remaining in the vicinity of our cities, and elsewhere the plant is rapidly disappearing.

FRINGED GENTIAN (*Gentiana crinita*), immortalized by the poet Bryant, is an exquisite plant. When

FRINGED GENTIAN

This beautiful flower needs your protection. It is fast disappearing.

Bryant wrote his beautiful ode, little did he realize that in so doing he would create a demand for the beautiful blue blossom that would almost spell its doom. As a result of persistent hunting, fringed gentian is today one of our rarest wild flowers, although recent efforts on the part of the New York Botanical Garden to scatter the seeds of this species have reëstablished it in regions where it once disappeared.

Fringed gentian is one of the last flowers to bloom in the fall.

"Thou waitest late and com'st alone
When woods are bare and birds have flown,
And frosts and shortening days portend
The aged year is near his end."

GOLDENROD

These slender, swaying wands of flowers change field and roadside into blankets of gold.

GOLDENROD (*Solidago* spp.), perhaps the most characteristic of our native wild flowers, exists in rank abundance in America while in Europe it is cultivated and cherished in gardens. There is a bewildering array of species flung from coast to coast and from border to border. The goldenrod has frequently been mentioned for honors as a national floral emblem. The goldenrods are among our most distinctive species and form a partnership of color with the asters that covers our autumn countryside with a blanket of gold and royal purple.

HEPATICA

Even under the snow hepatica lifts its dainty bloom. There is "nothing fairer, if as fair," said John Burroughs.

The common notion that goldenrods are responsible for hay fever is false since all hay fever plants are wind-pollinated and goldenrod is distinctly an insect-pollinated plant. Of course if a bouquet of the yellow blossoms is brought into the house, placed on a mantel, there to dry and allow the pollen to scatter by gravity, hay fever may start, but ordinarily the glorious goldenrod is innocent of causing this baneful malady.

HEPATICA (*Hepatica triloba*) is another early woodland bloomer noted for the delicacy of the coloration of its flowers. The common name means "liver," an allusion to a fancied resem-

blance in the shape of the leaf to a liver. In the olden days when people believed that when a plant part resembled a human organ it could be used to cure ills of the resembled organ, a brew from the leaves of hepatica was regarded as a remedy for liver trouble. Modern medical science finds nothing to support such queer notions.

INDIANPIPE (*Monotropa uniflora*) is one of the oddest members of our flora. Pure white and absolutely without chlorophyll, it obtains its

MARSHMARIGOLD
This familiar spring flower, which resembles the buttercup, is a great favorite of the honey bees.

nourishment from decaying vegetable matter. It is a weird, clammy-looking plant that well deserves the common names "ghost flower" and "corpse plant," frequently applied to the species.

The single flower, the bowl of the Indianpipe, droops until seeds mature, when the plant once more lifts its head proudly among its fellows.

JACK-IN-THE-PULPIT (*Arisaema triphyllum*), or Indian turnip, so called because the Indians formerly boiled the bulb and used it for food, is a denizen of moist woods. It may be all right to eat the bulb after boiling, but do not attempt even to taste it raw since the flesh is filled with tiny needle-like crystals that penetrate the tongue and mouth parts, causing severe burning. The spadix, or spike, with the overhanging spathe, or enclosing leaf, suggests a preacher in a sounding-board pulpit, hence the common name. Since the Jacks are in danger of extinction in some parts of their range due to promiscuous picking, it has been suggested that the text of Jack's sermon could very appropriately be "enjoy us but do not destroy us."

MARSHMARIGOLD (*Caltha palustris*), known to country children as cowslip, enjoys the banks of streams, swamps and other wet places. The leaves are edible and often used by country people as greens. The flowers are brilliant yellow and resemble huge buttercups.

MAYAPPLE (*Podophyllum peltatum*) needs little introduction since the sweetish fruits and white blossoms are familiar to all country youngsters. The habit of eating the fruit should not be encouraged, since an overdose may prove disastrous. The leaves and the creeping roots of this plant are poisonous. The roots are used in medicine but workers who grind the dried roots must wear masks, since inhaling the dry powder of Mayapple may cause severe illness.

MOUNTAIN-LAUREL (*Kalmia latifolia*) is another of our magnificent native shrubs. In spite of its attractive appearance, however, the foliage is exceedingly poisonous when eaten by hungry live stock, as many a farmer has discovered to his sorrow. The common name, lamb-kill, applied to the plant refers to its poisonous properties.

When the flowers open the ten stamens are bent like little springs by the attachment of the tips to the

petals. Touch these arched stamens with the tip of the finger and immediately the stamens snap, dusting your finger with yellow pollen, although the plant prefers that the trap be released by a bee or other pollinating insect rather than waste its golden treasure for the mere amusement of mankind. The wood of mountain-laurel is used in the making of rustic furniture and spoons, while during the World War many a "French briar" pipe was carved out of the roots of our own mountain-laurel.

ORANGECUP LILY (*Lilium philadelphicum*). When we are asked to "consider the lilies of the field," either the erect-flowered, vermilion wood lily or its more gorgeous cousin, the Turk's-cap lily, would be worthy of our attention and study. The spots that dot the petals of both these glorious species assist pollinating insects to find the rich store of nectar contained at the bases of the petals. Since few can resist the temptation to gather these attractive blossoms, many of our wild lilies are gradually disappearing.

PINK AZALEA (*Azalea nudiflora*), wrongly called wild honeysuckle, is

POLLINATION OF LAUREL

Although the plant is waiting for a bee you can release the pollen with the tip of your finger.

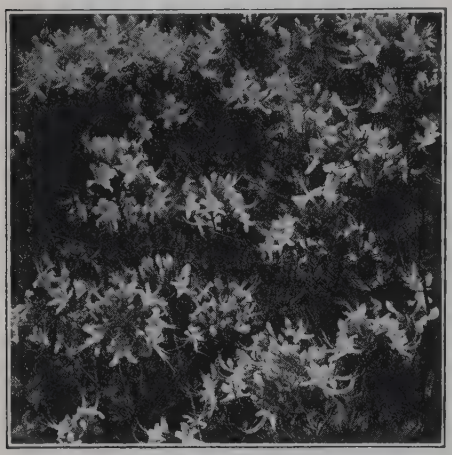
one of our floral aristocrats. The flowers usually develop before the leaves, presenting a strikingly handsome appearance. Occasionally one may find growing on azalea bushes a curious juicy, pulpy growth called "Mayapple," which is relished by

MOUNTAIN-LAUREL

A beautiful evergreen shrub with glossy, dark-green leaves. The magnificent blooms appear in June. The mountain-laurel has been chosen as the state flower by Connecticut.

many on account of its cooling taste. This is caused by a fungus.

Honey from the nectar of the azaleas has long been reputed to be poisonous although investigation by the United States Department of Agriculture has failed to confirm this belief. On ac-



PINK AZALEA

The flowers often appear before the leaves, thus lending a kind of Japanese grace to the plant.

count of their charming beauty, wild azaleas are eagerly sought by collectors and the day may not be long distant when this gorgeous plant may exist only in the cultivated state.

PINK LADYSLIPPER (*Cypripedium acaule*), sometimes known as moccasin flower, is without question one of our finest wild flowers. A member of the tropical orchid family, this beautiful plant is having a hard time maintaining itself under our conditions, a task in which it is being severely handicapped by flower vandals who pluck the magnificent blossoms at the first opportunity. A Chicago school teacher who took a nature study class into the wonderful dune region of northern Indiana, later boasted that she and her class picked over a thousand ladyslippers during a single afternoon.

The common name, moccasin flower, alludes to the shape of the blossoms, suggested by the footwear of the Indians. The redman thoroughly appreciated the beauty of these blossoms which were used in certain ceremonials and as hair ornaments by Indian maidens.

There are a number of other ladyslippers, most common of which is the yellow variety (*Cypripedium parviflorum*). Persons with sensitive skins should avoid these plants, since the hairs on the flowering stems may cause a severe skin rash somewhat resembling ivy poisoning.

PITCHERPLANT (*Sarracenia purpurea*) grows in bogs and is particularly interesting on account of its curious habit of capturing and drowning insects and possibly utilizing the decaying bodies for its own nutrition. The traps in which the insect victims are captured are the pitcher-shaped leaves, which are usually half filled with water. Inside the rim is secreted a sticky substance that attracts insects, while a slippery platform directly beneath the sticky area causes the animals to fall into the water. Downward pointing hairs prevent flies, beetles, or other prisoners from emerging, and the helpless victims soon drown.

RHODODENDRON (*Rhododendron maximum*) is a magnificent shrub or small tree, a spectacular plant that each spring enlivens almost the entire Allegheny Mountain region with its colorful bloom. Attractive both in flower and foliage, rhododendron is one of the finest of our native plants. The species is frequently found under cultivation.

At the base of each flower cluster there is a sticky ring that protects the flowers against ants and other robber insects in the same manner that a band of fly paper around the base of a

tree protects it against caterpillars creeping from the ground.

SKUNKCABBAGE (*Symplocarpus foetidus*), although not particularly attractive, is interesting and enjoys the distinction in many localities of being

SKUNKCABBAGE

This lowly relative of the stately calla lily proclaims the arrival of spring in the very teeth of winter, often appearing in February.

the earliest flower to bloom. It is not uncommon for skunkcabbage flowers to develop in the double protection afforded by the snow blanket and its own fleshy spathe.

The root system is cord-like and quite intricate. The strong odor possessed by all parts of this plant suggests the reason for the common name. Skunkcabbage is found along streams and in low wet places.

SNAPWEED (*Impatiens* spp.), often called jewel weed or touch-me-not, owes its common names to the hanging flowers and to the peculiar habit of the ripe fruits which shoot their seeds considerable distances at the slightest touch. A number of old settlers in southern Indiana have said that the macerated stems of jewel weed were used by the Indians as a remedy for ivy poisoning and several trials by the writer seem to verify the Indian views regarding the value of this treatment.

SOLOMONSEAL (*Polygonatum biflorum*) is a common woodland species the most interesting feature of which is the perennial fleshy root. A new "seal" is formed each year, the seal being simply the scar made by the death of the previous year's stem; so it is possible to count the age of the plant by the number of seals on root.

Solomonseal is frequently confused with the false Solomonseal from which it can readily be distinguished by the fact that the flowers and berries hang in pairs (rarely in groups of from three to eight) from the leaf axils, whereas the flowers and fruits of the false relative are clustered at the tip of the stem.

SPRINGBEAUTY (*Claytonia virginica*) sometimes grows in such profusion as to be among the most spectacular of our early bloomers. The

SPRINGBEAUTY

Delicate clusters of dainty, starry blossoms which adorn the moist spring woods and low meadows.

plant suffers little from picking on account of the fleshy bulbs which send up new flowers to replace those picked. The bulbs are said to be edible. It thrives in open woods and in fields from the Mississippi River to the Atlantic coast.

SUNDEW (*Drosera rotundifolia*) grows in company with the pitcher-plant and is endowed with the same villainous insect-catching habits. Instead of drowning its victims, however, the sundew catches them by means of a sticky substance on the tips of the leaf hairs. The struggling insect is held like a fly on fly paper and soon perishes miserably, after which the leaf folds around the little corpse until it is digested.

TRAILING-ARBUTUS
Fragrant with the breath of spring. This shyest of flowers prefers its forest home and usually pines away when taken from its native haunts.

TRAILING-ARBUTUS (*Epigaea repens*), frequently called the "sweetest flower that grows," is one of the most charming of our native plants. Following in the wake of the last snow, the lovely blossoms arise from creeping stems on which grow the oval, leathery leaves that seem to have rusted under the snow blanket. The common name, Mayflower, by which the plant is known in New England, owes its origin to our Pilgrim forefathers who regarded the handsome waxy-white blossoms as a symbol of hope after that first dreadful winter.

Arbutus has so long been a victim of the flower vandal that the incomparable plant has all but disappeared. As the state flower of Massachusetts, it is now protected in that commonwealth by rigid laws. The practical extermination of the plant over large areas is all the more tragic when it is realized that the flowers can be gathered with little harm to the plant if the flowering stems are cut with scissors or knife at the base, instead of dragging out the creeping stems in a vain effort to get long-stemmed flowers.

TRILLIUM (*Trillium* spp.), also called wake-robin, owes its common name to the fact that all parts of this plant from leaves to petals are built on a plan of three. There are several species of trillium, ranging from the ill-scented purple kinds, to the beautiful painted trillium with its crimson-stained white petals. The odor of the purple species somewhat resembles that of decaying flesh, which probably accounts for the fact that the flowers are pollinated by carrion flies. Other species of trillium are pollinated by bumblebees. The trilliums are largely woodland species and they all originate from fleshy roots.

WHITE TRILLIUM
Frequently found in the woodlands in attractive groups.

VIOLET (*Viola* spp.), emblem of modesty, is among the most familiar of our wild flowers. Few know that most species of violets produce two kinds of flowers, the ordinary blossoms which are cross-pollinated and the self-fertilized or cleistogamous flowers, located at the bases of the stems. These self-fertile flowers have no handsome petals, since the color of petals is designed to attract pollinating insects and the cleistogamous flowers do not depend on insects for pollination.

Violets range in color from blue to yellow and pure white. Handsomest and largest of its kind is the beautiful birdsfoot violet.

WATERLILY (*Castalia odorata*) takes front rank among the world's floral beauties. The stem is a huge fleshy affair that reposes in the mud on the bottom of the pond or river and no amount of flower picking will destroy this plant. Our common waterlily is related to the gorgeous *Victoria regia* of the Amazon, a plant with flower buds as big as the human head and huge floating leaves that can easily support the weight of a child. The common yellow pond lily is a comparatively unattractive cousin.

WATERLILY

This lovely queen of all water plants can be grown successfully in the home garden.

WILD ROSE (*Rosa* spp.), in spite of its pronounced beauty, should not be allowed to grow along fence rows and other farm waste places since the plant harbors plant lice that are strongly suspected of distributing serious diseases of potatoes and tomatoes in much the same manner that mosquitoes spread yellow fever in man.

VIOLET

The common blue violet, shown here, is one of the most satisfactory flowers for a beginner starting a wild flower garden.

SEEDS OF COMMON WEEDS *Courtesy U. S. Dept. Agr.*

The larger views show the magnified appearance of the seed while the smaller views show the natural size of the seed. Beginning at the left are shown ox-eye daisy, Canada thistle, corn cockle and wild carrot.

WEEDS

WHEN early man selected certain plants to grow for food purposes and other plants had to be destroyed to make room for the selected ones, the weed problem began and it has been with us ever since. In other words, weeds are plants that have the habit of growing where they are not wanted.

During the long process of becoming domesticated, our cultivated plants have had most of the fight taken out of them. Were it not for the help of man in the battle against weeds, corn, wheat, potatoes and other crops would soon disappear since they have been trained toward usefulness while the weeds have always been trained as fighters and the two characteristics do not ordinarily go together.

During recent years it has been found that the main object in the cultivation of corn and other crops is not to form a soil mulch, as is commonly supposed, but rather to kill the weeds. If weeds are prevented from growing, it matters little whether or not the soil is cultivated after the seed bed has been prepared in the spring. In general, were it not for the weeds, the farmer could prepare the land, plant his crop and forget about it until harvest. In certain heavy soils which check or crack badly, cultivation may be needed to fill the openings and prevent evaporation from the lower soil layers.

Since the main object of cultivation seems to be to destroy weeds, implements should be built to kill weeds rather than just to stir up the soil. For this reason, cultivators equipped with knives or sweeps are better than the shovel type now in common use, since the knives cut the weeds about two inches below ground, whereas shovel cultivators may do little damage to such weeds as Canada thistle and wild morning-glory. Knife cultivators, however, cannot be used on rough, rocky land.

Farms can be kept reasonably free of weeds if the work is done in an intelligent manner. There really is not much excuse for land becoming foul with weeds. Not only do the weeds greatly decrease the yields of crops, but they largely affect the market value of the farm since a well-kept, trim farmstead can usually be sold at a much higher figure than can one on which weeds run riot.

THE FOUR CLASSES OF WEEDS

In destroying weeds, a knowledge of their life is necessary. Weeds are divided into four classes, annual, winter annual, biennial and perennial.

Annual weeds sprout from seeds during the spring or early summer, mature a crop of seeds and die before winter. In this class belong ragweed, cheat and cocklebur. Annuals can be controlled and finally destroyed by

cutting or burning before seeds form.

Winter annuals grow from seeds that sprout in the fall, forming clusters of leaves from which seeds develop the following spring, as yellow rocket and peppergrass. To control, prevent formation of seeds.

Biennials form clusters of leaves the first year from which seed stalks grow the second year, after which the plants die. In this class belong common mullein and wild carrot. If cut while in early flower and before seeds form, biennials gradually disappear.

Perennials live from year to year by means of creeping or fleshy roots, underground stems, bulbs and tubers. In this class belong Canada thistle, quack grass, wild morning-glory, poison-ivy and many others that are considered among our worst offenders. In controlling perennials it is usually necessary to starve the underground parts by preventing the formation of green leaves since it is the leaves that manufacture the food that keeps the below ground growth alive.

INTERESTING FACTS ABOUT SOME COMMON WEEDS

CANADA THISTLE (*Carduus arvensis*). Wherever Canada thistle appears, land values usually decline. The pest spreads by means of wind-carried seeds and by creeping roots. Large areas of Canada thistle can be destroyed in three years with a good stand of alfalfa. For this purpose, the Grimm variety is usually best. Small patches may be permanently destroyed in a single season by cutting below the ground once a week from spring until frost.

CHICKWEED (*Stellaria media*) is a native of Europe that has made itself so thoroughly at home in America that it is now one of our commonest weeds. Although a delicate-looking plant, chickweed is one of our earliest bloomers, sometimes forming seed before the last snow has melted.

CORN COCKLE (*Agrostemma githago*) is a handsome scoundrel in wheat fields throughout the United States. The seeds are poisonous and were formerly responsible for a disease called "githagism" that was prevalent in France and other parts of Europe, although modern milling methods have practically eliminated all danger from this disease. The purple flowers sometimes present a striking sight in badly-infested grain fields.

DANDELION (*Taraxacum officinale*) is widely distributed. The name is from the French *dent de lion*, meaning "lion's tooth," and refers to the jagged edges of the leaves. The flowers are handsome, but the plant is a troublesome weed in lawns and pastures and in alfalfa fields. A spray of iron sulphate solution has been found valuable in killing dandelions in heavy turf. The tender leaves are often used as cooked greens.

Courtesy Nature Magazine

DANDELION

One of the most popular flowers with young children. Its long tap-root makes it very hard to exterminate.

JIMSONWEED (*Datura* spp.), a vile-smelling, ill-tasting plant, possesses the sole merit of beautiful blossoms. All parts of the plant are poisonous and the deaths of children have been reported due to eating the prickly fruits,

while illness has been traced to the practice of blowing soap bubbles through the elongated flowers.

The drug known as "truth serum," so called because after injection a person is supposed to answer all questions truthfully, is derived from Jimsonweed.

MULLEIN (*Verbascum thapsus*), familiar inhabitant of old pastures, is noted for the woolly covering of its leaves. During the winter a number of destructive insects hibernate in the woolly overcoat, a good reason for destroying the plant. In the olden days a tea was brewed from the leaves. The torches used in Roman triumphs and in other processions were made by dipping the heads of the mature stalks of common mullein in tallow.

POISON-IVY
A familiar sight on many farms. Sensitive persons should give this plant a wide berth.

POISON-IVY (*Rhus radicans*). Ivy poisoning is due to a heavy oil contained in all parts of the plant. After contact with poison- or three-leaf ivy, the oil can usually be removed by washing several times with cheap laundry soap. In case the blisters begin to develop on the skin, wash thoroughly and bathe with extract of grindelia (obtainable at any drug store) diluted with five parts of water. This will lessen the itching. Baking soda is also useful. On open ivy sores do not use sugar of lead since it may cause lead poisoning that may prove serious.

WILD CARROT
One of the most common of pasture and meadow weeds.

WILD CARROT (*Daucus carota*), often called Queen Anne's lace, is simply the common garden carrot run wild, as anyone can verify by smelling the tough, woody roots. So wild has this plant become that it is rapidly taking rank as one of our worst farm weeds.

The common name, Queen Anne's lace, refers to the delicacy of the flower clusters. Another common name frequently applied to this species is "bird's nest," in allusion to the shape of the flower head, which curls inward to form a hollow nest as the flower stalk dries after fertilization.

WILD MORNING-GLORY (*Convolvulus sepium*). Land infested with wild morning-glory or bindweed should be plowed and hogs allowed the run of the land since swine are fond of the juicy, creeping roots. The knife type of cultivator is far better than the shovel type where the glories grow. After the last cultivation of the crop, sheep can be turned in with profit since they eat the tops, thereby weakening the roots, with little damage to the corn

RED OAKS IN MIDSUMMER, WASHINGTON, D. C.

SHADE TREES

"I think that I shall never see
A poem lovely as a tree."

WHEN Joyce Kilmer, the soldier poet, wrote these lines, he suggested a portion of nature study that is open to every one of us. We need not travel to distant places to study trees. They invite us from our own dooryards or down our own streets. They are our neighbors; and surely we shall be better citizens for having learned something of their ways and habits through the changing seasons.

To appreciate the value of trees, let us imagine for a moment a treeless world. When the artist would paint a scene of utter desolation he shows a barren wind-swept plain; when he would picture peace, plenty and contentment, he frames the landscape with friendly trees.

In the following volume is the story of fruit trees and of forests and of the lumber industry. In this article are glimpses of some of our familiar trees, which provide shade and with their foliage delight our eyes and soothe our nerves. The trees of our communities, breathing out moisture into the air, are health-builders. Because of the benefits that come from trees, we have our Tree Days and our Arbor Days; boy scouts and girl scouts and other club members have formed the habit of planting trees; some of the finest memorials to those who have passed on are trees planted in loving remembrance.

How to plant a shade tree

Trees from the woods frequently are long-rooted and not easy to transplant. It is best to use nursery stock, where the trees have been transplanted every two years to insure an abundance of roots close to the trunk. Trees should be straight and healthy. Various sizes are used, but a good average is from ten to twelve feet in height,

and with trunk or stem from two to two and one-half inches in diameter.

To start the transplanted tree on a long span of life, a proper hole must be provided, and for a ten or twelve-foot tree this should be from four to

TREE PLANTING
Holding the tree in place and filling in properly with dirt.

four and one-half feet square and three feet deep. Good soil and drainage should be afforded. The mutilated ends of roots should be removed and the top severely pruned. In the picture the various stages in correct planting are shown, and the protecting box is illustrated.

Some Valuable American Shade Trees

ACACIA (*Acacia* spp.). The acacias, or wattles, form a large group of evergreen shrubs and trees much used in California. Although often too small to make much shade, such species as the blackwood acacia and the silver wattle attain a height of sixty or seventy feet. Gum arabic is secured from a species of acacia that grows in Africa.

AILANTHUS (*Ailanthus altissima*), or tree of heaven, was an immigrant from China. Coming into our country in 1820, the ailanthus became popular at once on account of its luxuriant growth in poor soil and in the midst of the smoke, dust and hot pavements of the city. In the spring the odor from the blossoms of the staminate (male) trees is objectionable, and for this reason pistillate (female) trees only should be grown.

ASH (*Fraxinus* spp.). The snug-fitting bark, broken into little plates, gives the ash a neat, attractive appearance in the winter woods. The winged seeds, pointed like darts, readily identify this tree.

The white ash is a large, oval-shaped tree, with white leaf linings, which give it its name. The green ash is rendering a real service in the Great

PROTECTION
Placing the protecting box around the tree.

American Desert, providing shade along the roads, and lending comfort to the homesteads in that region. The blue ash hides its bluing in its inner bark, and when this is crushed in water the dye appears. It is a

hardy tree, a quick grower, ornamental and a provider of shade.

The mountain ashes belong to an entirely different family. They are small trees with handsome leaves, flowers and fruit.

BIRCH (*Betula* spp.). The Indians framed their tents and built their canoes of the paper or canoe birch, the broad-leaved tree that grows farthest north. Today we prize the birches most for the contrast given by their gleaming trunks and delicate branches, as they stand among the darker trees. Their purple tops are very ornamental in the early spring landscape. Birch bark is rich in oil and woodsmen often use the inner bark as a means of starting fires on damp days.

The American white birch is a native, while the white birch of Europe is an imported species seen in parks and gardens. There are also red, yellow and black birches.

CATALPA (*Catalpa catalpa*). The broad, bright-green leaves and the great clusters of showy flowers give this tree, in midsummer, a luxuriant appearance. Later in the season the leaves fall, and the ungainly branches stand out all too plainly. The long, pencil-like seed pods hang on until dry, and in winter burst open and release multitudes of feathery seeds. The pods resemble stogies, which accounts for the name sometimes given of "cigar tree."

ELM (*Ulmus americana*). The American elm is sometimes called the white or water elm. What would the New England landscape be without these giant spreading trees? In town and country they abound, standing alone, lovely as great feathery vases, or united in avenues completely arched over with the mighty top boughs. Every school boy has heard of the Washington elm, until recently growing in Cambridge, but now a victim of the civilization that pressed too close.

Elms were taken from the virgin forest by the early colonists and planted near their homes. Through the years the trees have grown to great size. Larger or smaller elms are found everywhere east of the Rockies, and

BLACKWOOD ACACIA

Blackwood acacia, or black wattle, from Bakersfield, California.

today are largely used for street tree plantings.

The elm is the favorite nesting place for the Baltimore oriole, and in winter one may see the deserted hanging nests swinging from the high outer branches, where in summer complete protection was afforded from the gaze of the world.

GINKGO (*Ginkgo biloba*). The ginkgo, or maidenhair tree, came from Japan, and is now grown in our country, either in a cool climate or in a hot,

LINDENS IN WINTER

The lindens, or basswoods, are large, beautiful trees native to Europe and eastern North America.

moist one. It seems to be somewhat related to the conifers (cone-bearing trees, for example, the pines) on the one hand and to the ferns on the other. The peculiar, fan-shaped leaves identify the tree. It grows rapidly, and is a narrow, tapering tree when young, broadening and becoming flat-topped when mature. In China they roast the nuts as we do peanuts.

HACKBERRY (*Celtis occidentalis*). This excellent and attractive shade tree resembles the elm, but its "hacked" or warty bark and its thinner and longer pointed leaves enable the student to identify it. Hackberries, either green or ripe, may be found on the trees most of the year. They are eagerly sought by the birds. Sometimes a fungus produces deformities known as "witches brooms," that are very conspicuous during the winter.

HORSE CHESTNUT (*Aesculus hippocastanum*). The horse chestnut was an immigrant in the early days from southern Asia. It flourishes in open places and is ideal for a large country lawn. When in bloom the showy blossoms command attention—"a pyramid of green supporting a thousand pyramids of white." In autumn the small boy is sure to attack the tree for its smooth brown nuts. These are not good to eat, but are used as "conquerors" in boys' games that come as regularly as top spinning and games of marbles.

The horse chestnut is a close relative of the Ohio buckeye, a handsome but less desirable tree, with a disagreeable odor to its bark. Ohio, the "Buckeye State," derived its nickname from the fruit of this tree.

LINDEN (*Tilia americana*), or basswood, is a handsome tree, with leaves dark on their upper surfaces and light below, and with sweet-scented blossoms. The creamy white, honey-laden flowers are favorites with the bees. No tree has heavier foliage; and the dense roof of green is always a welcome retreat for cattle in the fields in the warm days of late summer.

When the pioneers entered the

Ohio Valley lindens were numerous and of great size. Most of them have fallen before the axe; and it is to be hoped that many second growth and planted trees may be left to reach the magnificent stature of the lindens of former days.

LOCUST (*Robinia pseudoacacia*). The black or yellow locust is a tall, slender, desirable shade tree in its earlier years As it grows old it becomes scraggly and untidy in appearance. Whatever may be the locust's shortcomings, it makes up for them in the spring with its delicate green leaves and its masses of heavily perfumed flowers, a delight to the eye and an invitation to myriads of bees.

The locust is a near relative of the sensitive plant, and, like its small cousin, has the habit of shrinking from the touch. On rainy days and toward evening also the leaves shrink, rising again with the coming of the morning sun.

MAGNOLIA (*Magnolia grandiflora*). In the South, after a night of rain, the sun comes out, revealing the magnolia as a truly royal tree. The stiff leaves glitter like polished metal, and the large, white, waxy flowers are given an excellent setting by the background foliage of dark green. The blossoms are from seven to eight inches across, and have a heavy odor. Those who live away from the home of the magnolia have little chance to see these wonderful flowers, as they cannot be shipped, turning brown at the slightest bruise. The leaves, however, are shipped north for Christmas decorations. Certain magnolias with smaller flowers grow in the northern states.

MAPLE (*Acer* spp.). Japan is one of the homes of the maples, and today two-thirds of the forest trees of Japan are maples. In the days of great luxury in Rome, people were passionately fond of tables made of curly maple. It is said that one of the kings of ancient Egypt had a circular table of maple four and a half feet in diameter, for which he gave its weight in gold—$60,000 for a single table.

One of the best species for the home lawn or for the park is the red maple.

MAGNOLIA
A splendid ornamental shade tree of the South.

It grows quickly, is beautiful all the year, and has no bad habits. In late March its delicate leaf tint of red is seen about the time the pussy willow breaks into blossom.

John Muir, the nature lover, said of the Oregon or broad-leaved maple, "No finer forest ceiling is to be found than these maple arches." This tree flourishes on our Pacific coast, where it grows to great size.

The soft or silver maple is a rapid grower, but the wood is weak and brittle, and it is not a desirable permanent shade tree.

In our eastern states the sugar or hard maple is important, and an excellent shade tree. The sap yields maple sugar. Long rows of the trees make

boundary lines and windbreaks, to which many an eastern farmer points with great pride.

OAK (*Quercus* spp.). Of all trees the oaks are perhaps the best for street planting. Many believe oaks are slow in growth and hard to transplant. Although the white oak and the live oak require many years to reach maturity, they compare favorably in growth even with the maples. Other species, as the willow oak, are more rapid in development.

Although America has fifty species of oaks, the white oak is king, a tree of strength and dignity. Its pale gray bark, with scaly ridges, reveals it in winter; its leaves of bright green, with pale linings, deck it in summer. Its nuts, or acorns, as all fruits of oaks are called, are eagerly eaten by animals.

The live oak is an evergreen, and the laurel, or Darlington oak, is practically an evergreen in the warmer sections of our country.

Although esteemed in Europe for over a hundred years, we have but recently discovered that the pin oak is an excellent shade tree. The little spur-like twigs that occur on the branches are crowded and choked to death and the "pins" that remain give this oak its name. The young tree is conical in shape, but grows oval as it matures. It is a rapid grower, and thrives in wet and heavy clay soils.

A flash of brilliant red in autumn reveals the lordly red oak, one of the best trees for street planting. It is the fastest grower of all the oaks.

The scarlet oak in autumn is even more gorgeous than the red oak. It has leaves more deeply divided than the red oak, and is one of our best shade trees.

The most valuable bark in the world comes from the cork oak, a native of southern Europe and northern Africa. (See story of "Cork" in the next volume).

PALMS and PALMETTOS. More than a hundred genera and more than a thousand species of palms are known. There are places where they supply almost every human need—food, shel-

LIVE OAKS

Avenue of live oaks in late summer, Biloxi, Mississippi. These are perhaps the handsomest street trees in the Southern States.

DATE PALMS
Canary Island date palms in midsummer, Merced, California.

ter and clothing. A few occur along the southern fringes of our country. In cities they furnish formal street decoration rather than shade.

A famous avenue tree is the Cuban royal palm now to be seen in southern Florida. It has a striking white stem, conspicuous in the landscape. Here also is found the true coconut palm. Washington palms are striking ornaments along the streets of southern California. In the deserts and along the canyon sides in the warm southwestern sections of our country the Washington palm occurs in groves or in lonely clumps, the trees rising often to a height of sixty or seventy-five feet.

The cabbage palmetto is an interesting palm growing in the Southwest. The bud, or "cabbage," is a juicy vegetable, eaten raw or cooked, but, since it is the growing point, its removal means the death of the tree.

POPLAR (*Populus* spp.). The poplars grow quickly, but most of them are not good shade trees, especially for cities. The cottonwood is a poplar, taking its name from the abundance of fluffy, cotton-like appendages, which carry the seeds. The southern cottonwood, or Carolina poplar, has been widely used on account of its rapid growth, but it is not a good permanent tree. The Lombardy is a black poplar that came from Italy. It grows straight and narrow, and is useful for shade only on very narrow streets.

A good shade tree among the poplars is the balm of Gilead. It takes its name from the fragrant wax that is found in the winter buds and coats the young leaves in the spring.

SWEET GUM (*Liquidambar styraciflua*). This beautiful shade tree is fortunate in being unusually free from insect and fungous enemies. In summer the star-shaped leaves and in winter the round bur-like seed balls are distinctive. The resinous sap or gum is fragrant and was described by an early Spanish explorer in Mexico as "liquid amber." Linnaeus, the great botanist, gave the name *Liquidambar* to the whole genus.

There is another group of entirely different trees to which the name "gum" is applied. This includes the black gum or tupelo, which belongs

to the genus *Nyssa*, named after Nyssa, a water nymph. The black gum grows abundantly in low swampy places. In autumn it has brilliant red leaves.

SYCAMORE (*Platanus occidentalis*). The sycamore is a large, open, quick-growing tree that is rapidly increasing in favor as a shade tree. When once you have seen the "hoary-antlered sycamore" with its flaky outer bark forever peeling off and showing big patches of new white bark beneath, you will never forget this tree. Its light-green foliage gives a distinct impression of airiness. The fruit is a hanging ball which has given the sycamore the additional names of buttonwood or buttonball tree.

TULIPTREE (*Liriodendron tulipifera*). This handsome shade and ornamental tree is attractive at all seasons of the year. In winter it stands out tall and symmetrical against the landscape. In flowering time the blossoms or tulips are attractive, resembling those of the magnolia. The blossom is the state flower of Indiana. The peculiar "chopped-off" leaves are a sure means of identification. They glisten in the summer sun and turn to a rich gold as autumn comes.

Plant trees wisely

Perhaps we may say that no tree is unlovely, but in planting there are certain trees that are best left off the list. We have hinted at certain faults among the poplars. The Carolina poplar, especially, is an untidy tree, dropping its leaves early in the autumn. It also is subject to injury from windstorms.

In modern tree planting there is little room for the box elder. The wood is poor, and the result is too often broken-down, unsightly trees at the time when a sturdy, well-proportioned shade tree should be thriving.

Willows are useful in their place. They have served valiantly in Holland, where their roots have held the banks against the destructive water of the sea, but as a shade tree the willow is light and weak and of little value.

Choose the tree with care, bearing in mind the location and the conditions for its future life. The tree must have food, and if nature does not provide it we must help. Stimulation with nitrate of soda is often helpful. Frequently water is sadly needed by a thirsty tree, especially in a city. The tree has its enemies which may be controlled by proper spraying. Pruning, and especially the removal of dead branches, are parts of the care to which a tree is entitled.

Take care of the tree and it will amply repay you. Its beauty, at all seasons of the year, will prove a source of delight. It will furnish shade and shelter in summer, and it will brighten your landscape in winter. It will make your street a better street, and it will help to make your house a home.

Photographs of shade trees by courtesy Bureau of Plant Industry, United States Department of Agriculture.

OBSERVING INSECTS OUT OF DOORS
The author is pointing out some interesting insects and explaining their habits. There is no more fascinating study.

INSECTS

THE space occupied by insects in the world exceeds that of all other animal life combined, according to a statement made by the well-known naturalist, David Sharp. In the words of another eminent naturalist, if all the insects on the earth could be gathered together and placed in one pan of a gigantic scales, and all the other animals placed in the other pan, the insects would outweigh the other animals. Because insects are so much smaller than most other animals it would, of course, require almost unbelievable numbers, and yet this great abundance of insects is actually a fact. If we examine into or beneath a rotting log we will discover numerous beetles and larvae of many kinds. If we study a square foot of grass sod at any season we will be surprised at the numbers and varieties of insects present. If we study the inhabitants of a pond or stream we will find insect life abundant. In fact, insects occur almost everywhere and under almost every conceivable condition.

A HALF MILLION INSECTS

And so we may ask, why are there so many insects? Because of their small size and apparently delicate structure, they seem ill-fitted to withstand the many adverse conditions. This question at once calls to our attention the marvels of insect life. Probably no less than a half million different kinds of insects have been described as distinct species. Thus we find nearly 200,000 different kinds of beetles, 60,000 kinds of butterflies and moths, 50,000 kinds of bees and wasps, 40,000 of flies, 30,000 of plant bugs, and so on. If we study each of these insects we find some development of an appendage or part, some form or color or special activity, which fits it for its own life. Thus we find the honeybee with special adaptations to

gather pollen to feed the young in the hive, a special container to carry nectar from the flower to the hive, and a stinger to protect itself and its possessions against intruders. We find the small plant lice, or aphids, with a delicate structure which makes them

U. S. D. A. Illus.

COTTON BOLL WEEVIL

The snout beetle lays eggs in the developing bolls of cotton and the maggots hatch from these eggs and eat into the developing cotton boll as shown at *c*, ruining it.

susceptible to unfavorable weather or other conditions, and yet, because of their ability to reproduce and rapidly increase to enormous numbers in a short time, if conditions are favorable, we must recognize them as among the most important pests of growing crops. Land insects are provided with tubes through which the oxygen is carried to the tissues, while those kinds which inhabit water are provided with gills or other means to take the oxygen directly from the water, or, perhaps, as in the case of mosquito larvae, known as "wriggle tails," the insect frequently returns to the surface to obtain the oxygen direct from the air.

Harmful insects

Every boy and girl knows that insects destroy our growing crops. Probably you have seen the yellow and black striped potato beetles and their young, the red slug-like worms that destroy the foliage of potato plants. More than once you have found it necessary to throw away an apple because you have found, upon biting into the juicy fruit, that it was occupied by an apple worm—perhaps two. Yes, every plant, both wild and cultivated, has its own "bug" to attack it. Some plants have only one or two insect enemies, while others, as the corn plant, may be attacked by as many as 250 different kinds of insects. Some insects, as the potato beetle or the cabbage worm, feed only on one or a few closely related plants. Others, such as white grubs, grasshoppers and cutworms, will feed on almost any kind of plant.

Some insects, as lice and fleas, attack animals; others destroy stored products, such as peanuts and flour; still others attack the woodwork of buildings, and we know of one that burrows into lead pipe.

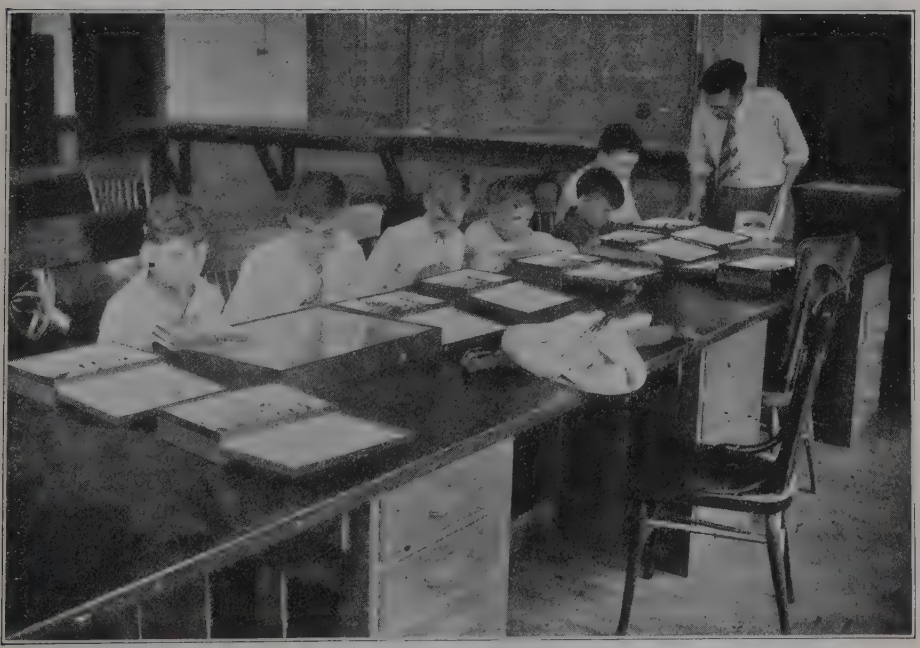
Aside from the fact that flies and mosquitoes and certain other insects are annoying during the summer months, we find that they may carry disease organisms. Thus, certain mosquitoes are responsible for outbreaks of malaria and yellow fever. Some kinds of plant diseases, such as melon wilt and potato leaf curl, are carried from one plant to another by insects.

Helpful insects

Although many insects are harmful, there are probably just as many that

PRIZE WINNING INSECT COLLECTION

This Indiana boy with his collection took the honors at the first Boys' and Girls' Club Insect Collection Contest, held at Purdue University.



STUDYING INSECTS

After collecting and mounting insects these boys find great pleasure in identifying the different kinds and learning how each lives.

are helpful. Strange to say, they are probably of most value as natural enemies of harmful insects. Nearly every insect is attacked and may be destroyed by some other insect. Nature has thus made a provision to prevent the harmful from becoming too abundant. If a harmful species becomes very numerous its natural enemies have plenty of food, and they, in turn, become very abundant and check the increasing numbers of the harmful ones.

PARASITES

The white bodies on the tomato worm shown here are the cocoons of a small wasp parasite which lives within the tomato worm.

There are two kinds of insect natural enemies. Some, as the ladybird beetle, are called predacious, because they eat other insects. The ladybird crawls about eating every aphid or scale insect it finds.

Other insect natural enemies are called parasites, because they live within or upon a single insect. An example is found in the parasite of the large green tomato or tobacco worm, which eats the leaves of tomato and tobacco. Nearly every boy or girl who has seen these worms in the garden has noticed some with white bodies on their backs. These white bodies are cocoons—not eggs, as some suppose. If we place a caterpillar bearing such cocoons in a glass jar with a cheesecloth top we find tiny blackish wasps issuing from them in a week or two. These little wasps lay eggs in other tomato worms. The maggots hatching from the eggs feed on the internal parts of the worm until full grown, and then cut a hole in the skin of the worm and come out and spin the white cocoons. Natural enemies of insects help greatly in preventing some destructive kinds from becoming too abundant.

The honeybee is valuable because it produces honey. The silkworm is the insect which is responsible for the production of silk.

Some insects help farmers by carrying pollen from one flower to another, and thus fertilize flowers. This is very important for the profitable production of large crops and fine fruit.

Insects help to dispose of dead carcasses which, if not assisted in their decay and disposed of by the aid of insects, might pollute the earth. And some insects are of value because they destroy obnoxious weeds, as for example, the thistle caterpillar which destroys Canada thistle.

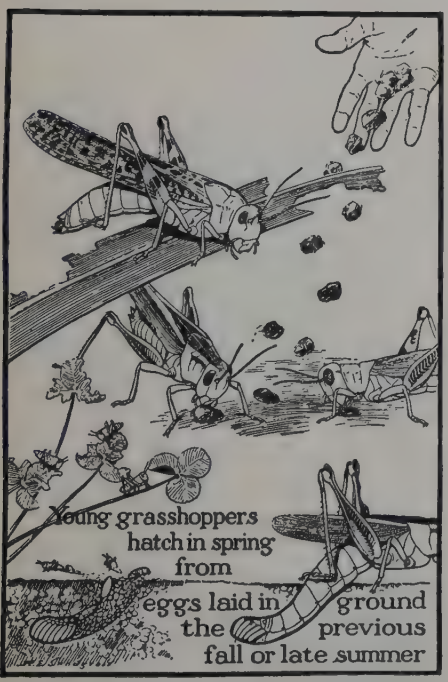
How insects live and grow

In general, there are two kinds of development or growth in insects. One we call incomplete and the other complete.

Insects with incomplete development seem to be of the most primitive kinds. They have, first, the egg stage, which, in insects, is always the beginning of life. The egg hatches into the second stage, known as the nymph. After the nymph has molted or cast its skin several times, it passes into the third or the adult stage. The egg stage is the beginning of life; the nymph is the feeding and growing stage; the adult is the fully grown individual ready to lay eggs. In this kind of development the young, hatching from the egg, resembles the adult. For example, the grasshopper has incomplete development. The nymph, or stage

hatching from the egg, resembles the adult grasshopper, except, of course, that it is smaller and does not have the wings or other appendages as well developed.

The other kind of development is known as complete. Here we have four stages. The first is the egg, the second the larva, the third the pupa, and the fourth the adult. The larva stage is the feeding and growing period, and larvae are sometimes called caterpillars, grubs or maggots. The pupa stage (the cocoon or chrysalis stage of a moth or butterfly) is a dormant period, during



U. S. D. A. Illus.

GRASSHOPPERS

Principal points in the life history of the insect. This illustration shows how to destroy grasshoppers with poisoned bran bait. This insect illustrates incomplete development.

which the insect makes the wonderful changes from larva to adult. In this kind of development the larva is entirely different from the adult. For example, the caterpillar is entirely different from the adult, which is usually a butterfly or moth; the maggot is not generally recognized by those unfamiliar with insect life as the

A CHEWING INSECT

This insect has strong jaws or mandibles with which it is able to cut off portions of the plant tissue. (From Slingerland and Crosby's *Manual of Fruit Insects*, Macmillan.)

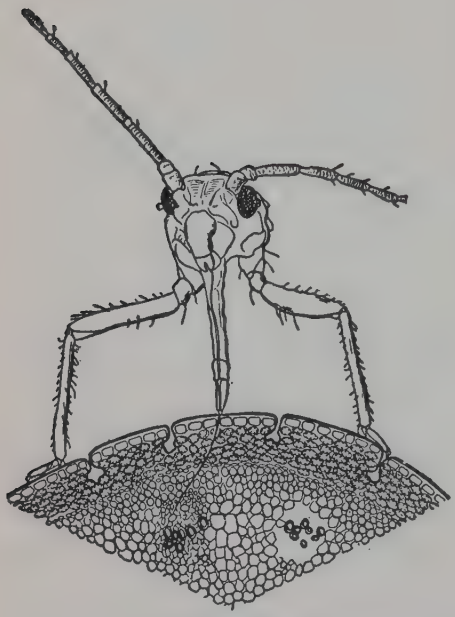
young of a fly; the white grub, which we find eating the roots of grass and corn, does not have any resemblance to its parent, the brown May beetle or "June bug."

It is a fine thing to be able to say, when you see a caterpillar, that it will turn into a butterfly or moth; or, if you find a grub, that it will eventually change to a beetle; or, that a legless maggot will soon become a fly. Every boy and girl, by observing and studying insects, will soon be able to recognize these different kinds and tell what further changes in their appearance will take place.

How insects feed

In general, insects feed in two ways. Some, as grasshoppers, beetles and caterpillars, have jaws or mandibles which can be used to cut off parts of a leaf or twig, which they take into their stomachs. These are called chewing insects. If a poison is placed on the surface of the part eaten, it will be taken into the stomach of the insect and will kill it. It is important to know the kind of mouth parts that an insect

has in order to know the kind of insecticide to use to kill it. For chewing insects we spray or dust the plant with a stomach poison, such as Paris green or arsenate of lead.



A SUCKING INSECT

A plant louse feeding, showing the sucking type of mouth parts. (From a German drawing in Slingerland and Crosby's *Manual of Fruit Insects*, Macmillan.)

Other insects, as plant lice, scale insects, plant bugs, and mosquitoes, do not have jaws and cannot cut off and take solid parts of the tissue into the stomach. They have beaks, by means of which plant and animal tissue can be punctured and the juice sucked. Insects with sucking mouthparts can take only the juice of a plant or animal, and, therefore, would not be destroyed by a poison placed on the surface of the leaf. They must be killed by an insecticide which destroys by coming in contact with the body, as the oil sprays, nicotine, lime-sulphur and soap. These are called contact insecticides.

We find other special kinds of mouth parts. The house fly has a lapping type of mouth. It can neither cut off tissue nor can it puncture tissue. It can only lap up liquids. Consequently, when a house fly attempts to eat a lump of sugar, it must first dissolve the sugar with saliva from its mouth, and then lap up the dissolved sugar.

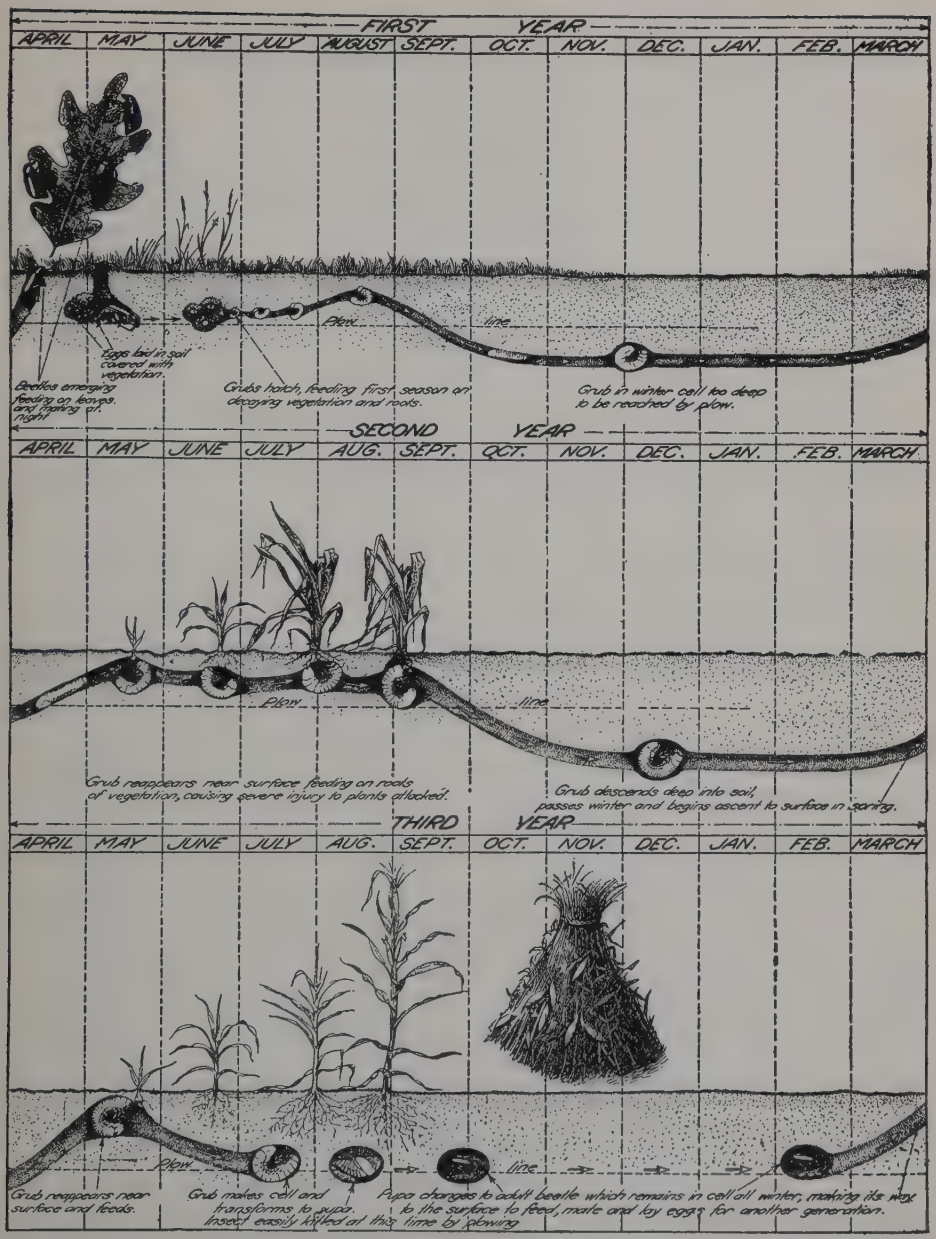
CLASSIFICATION — HOW TO GET ACQUAINTED WITH INSECTS

With such a variety of insects, it is necessary to have them so classified as to permit one easily to identify them. Classification is simply the systematic grouping of objects which are related or alike.

A LAPPING INSECT

Head of a fruit fly, showing the lapping type of mouth parts. (From Slingerland and Crosby's *Manual of Fruit Insects*, Macmillan.)

Insects are classified just as schools, offices and manufacturing plants are. The Class *Insecta* includes all animals which have an external skeleton and which, in the typical adult stage, have the following characters: a body divided into the head, thorax and abdomen; the head with two compound eyes, three simple eyes, a pair of antennae or feelers, and mouth


FIRST YEAR
APRIL MAY JUNE JULY AUGUST SEPT. OCT. NOV. DEC. JAN. FEB. MARCH
Plow line
Eggs laid in soil covered with vegetation.
Beetles emerging feeding on leaves, and figuring on flight
Grubs hatch, feeding first season on decaying vegetation and roots.
Grub in winter cell too deep to be reached by plow.
SECOND YEAR
APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH
Plow line
Grub reappears near surface feeding on roots of vegetation, causing severe injury to plants attacked.
Grub descends deep into soil, passes winter and begins ascent to surface in spring.
THIRD YEAR
APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH
Plow line
Grub reappears near surface and feeds.
Grub makes cell and transforms to pupa. Insect easily killed at this time by plowing
Pupa changes to adult beetle which remains in cell all winter, making its way to the surface to feed, mate and lay eggs for another generation.

Courtesy U. S. Dept. of Agr.

LIFE CYCLE OF WHITE GRUB

Diagram illustrating the complete life cycle of white grubs which covers a span of three years, showing the periods during which they can be killed by plowing. Note that the parent of the white grub is the brown May beetle or "June bug." This insect illustrates complete development as explained on Page 161.

parts; the thorax with three pairs of jointed legs, and usually two pairs of wings; the abdomen made up of a number of segments, with no appendages for moving about. Insects have no internal skeleton, but they do have an external skeleton or shell made up of a horny material called chitin. We might compare the skeleton of an insect with the armor of a medieval knight. This insect armor is thinner at the joints, which permits movements of the various parts.

Growth means increase in size, and occasionally the larval or nymphal insect finds it necessary to cast off its old covering and make a new one to accommodate its increased size. This chitin shell is further interesting because it is resistant to most acids and alkalis. This accounts for the finding of the shells of beetles or grasshoppers several years after the insect has died.

Insects therefore have characters which at once separate them from such closely related animals as spiders, mites, millipedes, and the like.

The Class Insecta is divided into smaller groups known as orders. Thus, we have the Order Orthoptera (grasshoppers, crickets, cockroaches, and related insects), Odonata (dragon flies and damsel flies), Homoptera (leaf hoppers, plant lice, scale insects), Hemiptera (true bugs, such as plant bugs), Coleoptera (beetles), Lepidoptera (butterflies and moths), Diptera (flies) and Hymenoptera (bees, wasps, and ants). Often the scientific name indicates the principal characters. One notices that most of the order names end in *ptera* which means "wing." Thus we have Lepidoptera which means "scaly wings," a character of all butterflies and moths; Diptera, meaning "two wings," a character of all flies; Coleoptera or "sheath wings," the outer wings of all beetles being sheath-like.

In turn, each order is subdivided into smaller groups called families. In the Order Lepidoptera (butterflies and moths), for instance, we have the Family Papilionidae, or swallow-tail butterflies; Hesperiidae, or skippers; Saturniidae, or giant silkworm moths; Noctuidae, or owlet moths; Geometridae, or measuring worms, and so on.

The family is made up of genera. Each genus includes insects very closely related. Under the genus we find the final subdivision to species. Take, for example, the common insect known generally as the corn ear worm. His complete classification is as follows:

Class Insecta
Order Lepidoptera
Family Noctuidae
Genus Heliothis
Species obsoleta

We use scientific names of insects because they are standard, while common names differ in different sections of the country. Thus, the combination of the genus and the species names—*Heliothis obsoleta* Fab.—is the scientific name of the insect and is recognized throughout the world, while the common name of the same insect is variously given as the cotton boll worm, tobacco bud worm, tomato fruit worm, and corn ear worm according to the crop attacked or the locality. Fab. is the abbreviation of the name of the man, Fabricius, who first discovered and named the insect. We might compare the naming of an insect with the name of a boy. Just as we name John Smith, so we name an insect, but instead of putting the given name first and the surname last, we reverse it, as Smith John.

Insect classification may seem complicated and difficult. It would be, if one attempted to sit down and learn a number of names "by heart." However, if you are interested in insect life, you will soon learn the system and

THE HOUSE FLY *U. S. D. A. Illus.*

At the left is a pupa and at the extreme right a larva or maggot.

find that each name has a meaning, which will be of great assistance in your studies and in your understanding of insects.

The two-winged insects or flies

The fly family includes many common insects, such as mosquitoes, house flies and gnats. They are different from all other insects because they have only two wings. But, if you will examine a fly carefully, you will find two little knobbed organs just back of the true wings where they are attached to the body. These take the place of one pair of wings and are called "balancers" because they help to balance the insect as it flies about. If one of these balancers is removed, the fly is unable to fly properly and acts just as you would if you were blindfolded. Flies have the four stages of development—egg, larva (often called a maggot), pupa and adult. Root maggots, leaf-miners and Hessian fly are examples of flies which are harmful to crops. Many others are parasites of different kinds of insects.

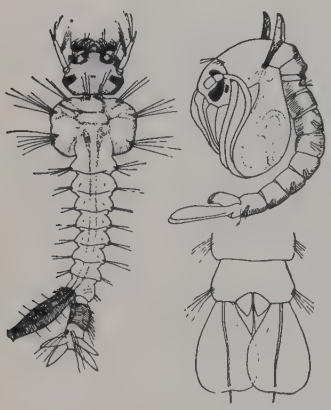
The life story of the house fly

The common house fly is to be found in every inhabited place in the world. Even in the coldest portions of the earth they are abundant. Arctic explorers tell us that flies are one of their greatest worries, more so even than the cold weather.

Every boy and girl should know about this insect, which is not only a nuisance but may carry disease germs. And if you understand where they breed and know their habits you will understand why they affect our health, and why we should try to kill all flies and avoid places where they are numerous.

Many times we have been told that the small flies which sometimes come into houses are young house flies. This is not true, for, once a fly takes on wings, it is fully grown, and never grows any larger. The mother fly is attracted to decaying odors to lay eggs, and so we find her laying eggs in manure and garbage. From these eggs small white larvae, known as maggots, hatch. They are without legs and eyes, but they need neither, for the mother fly has laid the eggs where there is such an abundance of food for her young that they do not need to search for it. These maggots feed on the decayed food, and in only a few

days complete their growth and then change to a brown pupa. Here they lie dormant for a few more days, and come out as adult winged flies. From the time the egg is laid until the adult fly issues may be only eight days. And



U. S. D. A. Illus.

LIFE OF A MOSQUITO

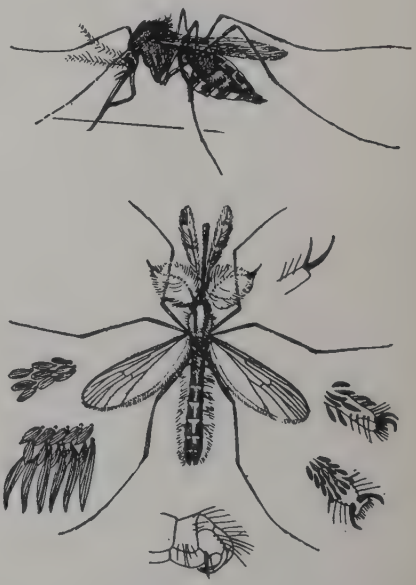
At the top is a "raft" of eggs which floats on the surface of the water. Below are larvae or "wiggletails." At the lower right is the pupa.

there may be great-great-great-grandchildren before the summer is half over. You will now understand why we are warned to "swat" the first appearing flies in spring; for every fly we kill early in spring means many million fewer flies by fall.

A fly is a peculiar insect, because, while it is attracted to decaying odors and inhabits filthy places, at the same time it seems to enjoy clean places as well. And so we find them traveling from dirty places and carrying disease germs on their feet into our homes. Here they crawl over our food and in so doing they bring the germs with them. If we can kill off the flies and prevent them from entering our homes, we will have less sickness.

And you may wonder how the fly carries these germs on its feet. If you will examine the foot of a fly under a microscope you will notice a pad to which dirt and germs stick. Thus it is an easy thing for the fly to carry these germs from one place to another.

Always remember where flies breed, how they carry disease germs into our homes, and that every fly killed early



U. S. D. A. Illus.

ADULT MOSQUITOES

Only the female, shown above, "bites." The male, shown below, has very feathery antennae.

in the spring is equal to killing millions of flies in late summer.

THE MOSQUITO

It would be desirable if the mosquito were not so clever and careful in her treatment of her eggs, for while many mosquitoes merely bite and cause one

to smart, some carry disease germs which kill thousands of people.

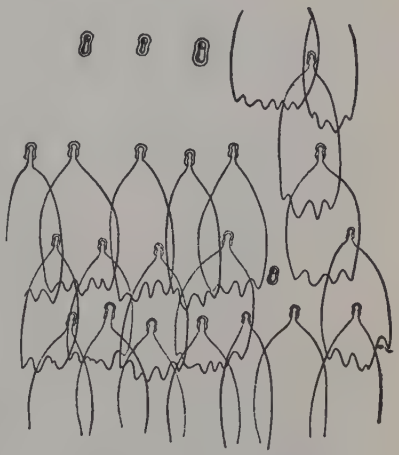
Female mosquitoes lay their eggs on or near water. In the case of certain species they are laid in moist mud, while in the case of one species capable of carrying a very deadly disease, the eggs are usually deposited above the margin of the water and do not hatch until the water rises to moisten them. In places where mosquitoes carry disease, men fight them, in some instances by covering the water with petroleum which, being lighter than water, floats on the surface, so that when the larvae come to the surface they cannot breathe and therefore die at once. Another method of fighting them is by draining the water from the breeding places.

THE SCALY-WINGED INSECTS—BUTTERFLIES AND MOTHS

The beauty of some butterflies and moths is unsurpassed. Their graceful flight and conspicuous and brilliant colors give them an attractiveness that is pleasing to everyone. The great variety and shades of colors and color patterns are the result of the scales which cover the wings. The individual scales when observed under a microscope are variously shaped, but in general resemble shingles of a roof and overlap on the wing as do shingles on a roof. The butterflies and moths have the four stages of complete metamorphosis or development, namely the egg; larva or caterpillar; pupa, which may be naked as a chrysalis or enclosed in a cocoon, and the adult.

Butterflies are usually more brilliantly colored than are moths. They are distinguished by the knobbed antennae or feelers and are day-fliers. Moths have slender or feathery antennae, and most of them fly at night. Furthermore, they are not usually as brightly colored as are butterflies.

Most of the larvae or caterpillars of butterflies and moths are plant feeders and many of them, such as the cabbage worm or white cabbage butterfly, European corn borer, tomato worm, and army worm, are harmful to cultivated crops in the larval stage.



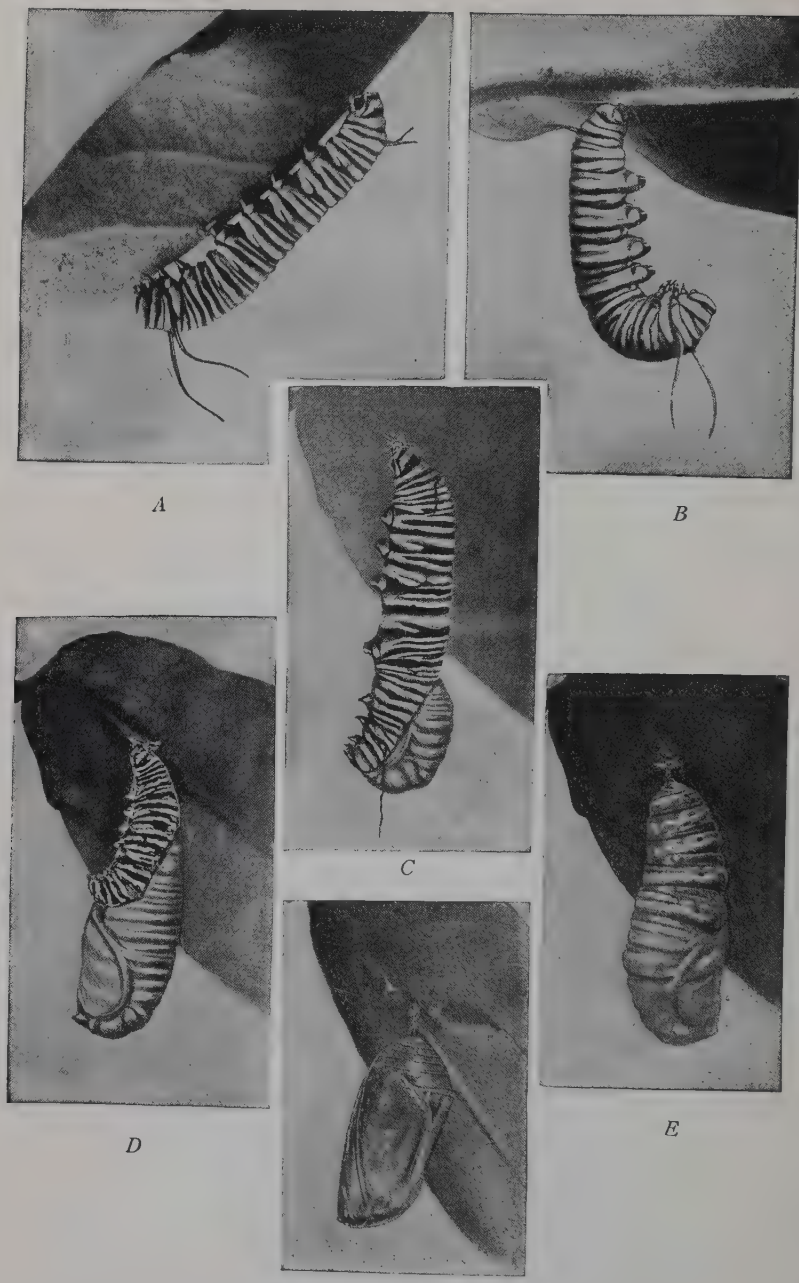
BUTTERFLY SCALES

Shingle-like overlapping of scales as they are arranged on the wing of a butterfly. (From Folsom's, *Entomology*, Blakiston's.)

The changes which take place in the life of these insects is probably more wonderful than in any other order of insects. In the larval or caterpillar stage they are feeding and growing rapidly and have chewing mouth parts which enable them to cut off and take into their stomach portions of the plant tissue. But when they change to the adult form they lose the chewing type of mouth and we find instead a long sucking tube through which they suck the nectar from flowers.

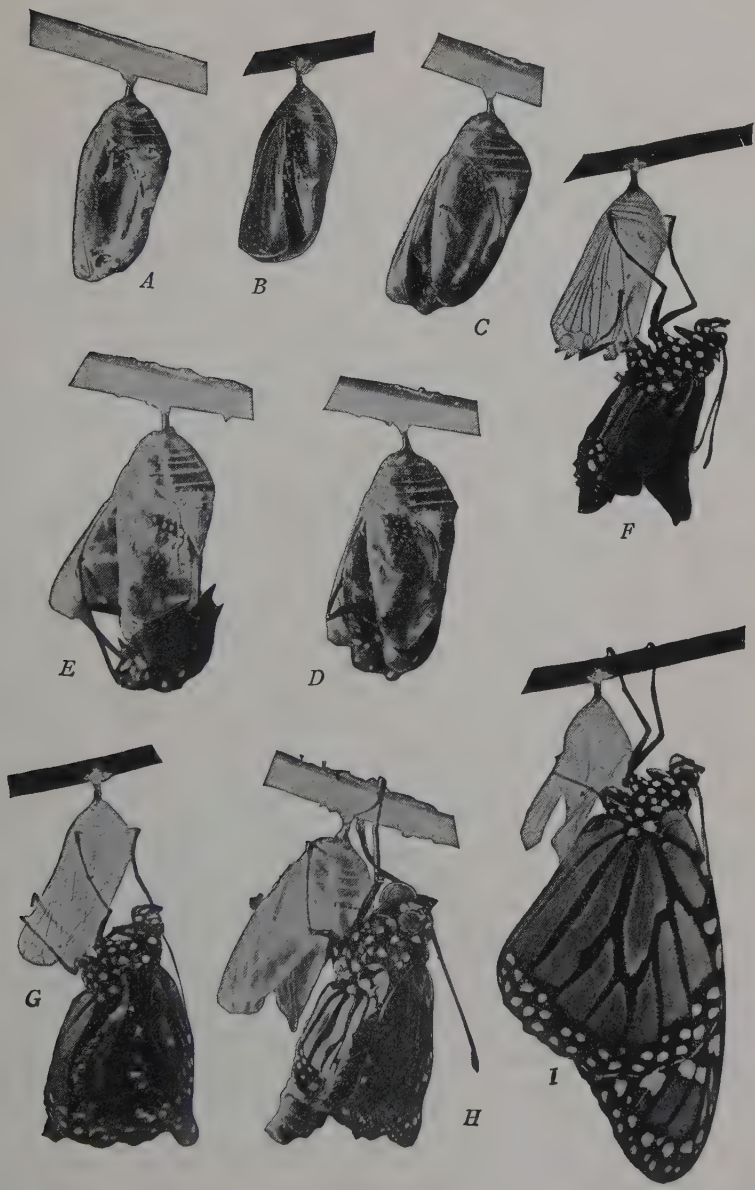
THE MONARCH BUTTERFLY OR MILKWEED CATERPILLAR

Let us take the Monarch butterfly as a typical example of this order of insects. The spherical eggs are laid on the leaves of our common milkweed. From these little eggs a caterpillar hatches and instinctively begins to



PUPATION OF MILKWEED CATERPILLAR

Successive stages in the pupation of the milkweed caterpillar, the larva of the Monarch butterfly (Anosia plexippus). A, the caterpillar completes its growth; B, attaches itself to the leaf; C and D, the skin splits along the back until gradually the pupa is exposed as in E. Finally, we have the completed pupa F. (From Folsom's *Entomology*, Blakiston's.)



THE BUTTERFLY COMES OUT

This interesting series of pictures shows the successive stages in the emergence of the milkweed or Monarch butterfly from the chrysalis or pupa stage. The adult or mature form gradually develops within the chrysalis and, after emerging, the wings expand to their normal size. The successive stages are not placed exactly in order on the page, but they proceed as indicated in alphabetical order—A, B, C, D, E, F, G, H, I. (From Folsom's *Entomology* Blakiston's.)

feed on the foliage of the plant. As the greenish yellow and black banded caterpillar feeds, it grows until it becomes full grown and it attaches itself to the leaf and gradually casts off the larva skin and there remains suspended from the leaf as the oval pupa or chrysalis. In this shell the insect gradually changes, and, after a short time, splits open the shell, and then emerges as an entirely different form, which, after it has expanded its wings, we recognize as one of our common reddish-brown winged butterflies.

This is but a single example. All of the thousands of different kinds of butterflies and moths go through a similar series of transformations, from a little egg, through the unsightly caterpillar stage and the mummy-like pupa to a beautiful butterfly or moth.

THE SHEATH-WINGED INSECTS OR BEETLES

There is a greater number of beetles than of any other order of insects. They are characterized by the horny, sheath-like upper wings which cover and protect the under or propeller wings beneath. There are four stages in the development of a beetle—the egg, the larva or grub, the pupa and the adult. The majority feed on plants or plant products and are therefore harmful, but a few—such as ground beetles and ladybirds—are beneficial because they destroy harmful insects. Common examples are potato beetles, blister beetles, snout beetles, flea beetles.

THE LIFE OF THE MAY BEETLE OR JUNE BUG

Every year, during May and June, the large brown June bugs are found flying to lights. They disappear, and are not again to be seen until another spring. By following the insect through its life we discover a wonderful change taking place. The beetles appear in spring—and, while they are attracted to lights, most of them fly to trees at night and feed on the foliage, returning to the ground just as the birds are awakening. It is well that they do not remain in the trees during the day, for birds are very fond of these beetles and would soon destroy them. Returning to the soil, especially grassy fields, the beetles lay eggs which look like large pearls. From these eggs small white grubs hatch. The grubs are the large white curled grubs with brown heads and are commonly called white grubs. Boys and girls who go fishing have no doubt found that they make excellent fish bait. These white grubs eat the roots of plants; and often when a plant wilts, an examination of the soil about the roots will reveal a grub or two which have been cutting off the roots. The white grub grows slowly, and it takes three years, as shown in the illustration, to become full grown and to change again to a beetle. Most kinds of May beetles mature in the fall but sleep quietly in their cells in the ground until the leaves are out the next spring, when they emerge and for a few weeks feed on the foliage of trees and lay eggs for the next generation.

THE LIFE OF A LADYBIRD

This beetle, although having the same four stages of development as a May beetle, is quite different in its life. The gayly red or yellow and black spotted beetles fly about until they discover a group of plant lice or aphids feeding on some plant. When they have found such a place they lay eggs on the leaf nearby, where their young, when they hatch, will have plenty of food because young ladybirds feed on aphids. And so when the larva hatches from the egg it attacks the nearest aphid and eats it. It destroys one after another of the aphids until it has become full grown, and then it changes

to a pupa and soon after to the adult ladybird beetle. But it only takes a few weeks to become full grown, and not three years, as in the case of the May beetle. Because they eat aphids and can increase their families to large numbers, ladybirds usually eat most of the destructive aphids by midsummer.

THE MEMBRANOUS-WINGED INSECTS — BEES AND WASPS AND THEIR RELATIVES

Bees and wasps are said to be the most highly developed insects. By that we mean that they have more adaptations and are better equipped to live a successful life. This highly specialized group of insects includes some which are harmful, for example currant worms, pear and cherry slugs, joint-worms, gall-producing insects and ants. However, the majority are beneficial. Some, for example, bees, which gather nectar and make honey, produce a valuable crop. Some pollenize fruit flowers, as do the bees and wasps. Others are parasites which kill harmful insects.

NEST OF SOLITARY WASP

The mud nest of a solitary wasp, showing the comb in which it lays its eggs.

Bees and wasps are characterized by four membranous wings with few crossveins, the hind pair smaller than the fore pair and the mouth parts made for chewing or for chewing and sucking. Usually the females have a more or less conspicuous egg-laying organ, called the ovipositor or this may be modified into a stinger, as in the case of the worker honeybee.

BUMBLEBEES AND NESTS

Eggs of the common bumblebees in their underground nests.

All members of this order have complete metamorphosis. In other words we find four stages in development, egg, larva, pupa, and adult, and the larva stage is quite different from the adult.

THE LIFE OF A HONEYBEE

If you have ever examined into a colony of bees, watched them flying to flowers to gather nectar, seen them store the nectar in the cells and feed the young bees, you have no doubt marveled at the wonderful organization among these insects, and have realized that the name "busy bees," so often given them, is a true one.

Bees are wonderful in many ways. They have adaptations to enable them to gather pollen which they bring back to the hive to feed the young, they can manufacture wax to build the cells in which they store honey, they have a honey stomach to carry the nectar back to the hive. Their wings enable them to fly long distances if necessary, and they have a stinger which they use to protect their home.

We find three kinds of bees living in the hive. The males are large individuals, which are called drones be-

cause they do no work. We have a queen in the hive, and she is almost continuously busy laying eggs. The most common kind of bee is the worker. The workers live up to their name for they have all the work to do; they gather nectar and pollen, feed the young bees and keep the home in order. It is the worker also which must do the fighting if the colony is disturbed.

SWARM OF BEES

An emigration of bees with their queen intent on founding a new colony. When bees swarm it is necessary for the beekeeper to go out and hive the swarm.

Unlike other insects, bees do not hibernate. A colony in good condition will contain from fifty to one hundred thousand bees and they all remain more or less active throughout the winter months. In order to remain active they must keep the hive warm in winter, which they do by clustering and fanning their wings, just as we clap our hands to keep warm. This will explain why we should keep the hive in a protected place during the winter, because, if exposed, the bees must work hard to keep the hive warm and by spring they will be worn out and unable to develop a large colony and gather much nectar.

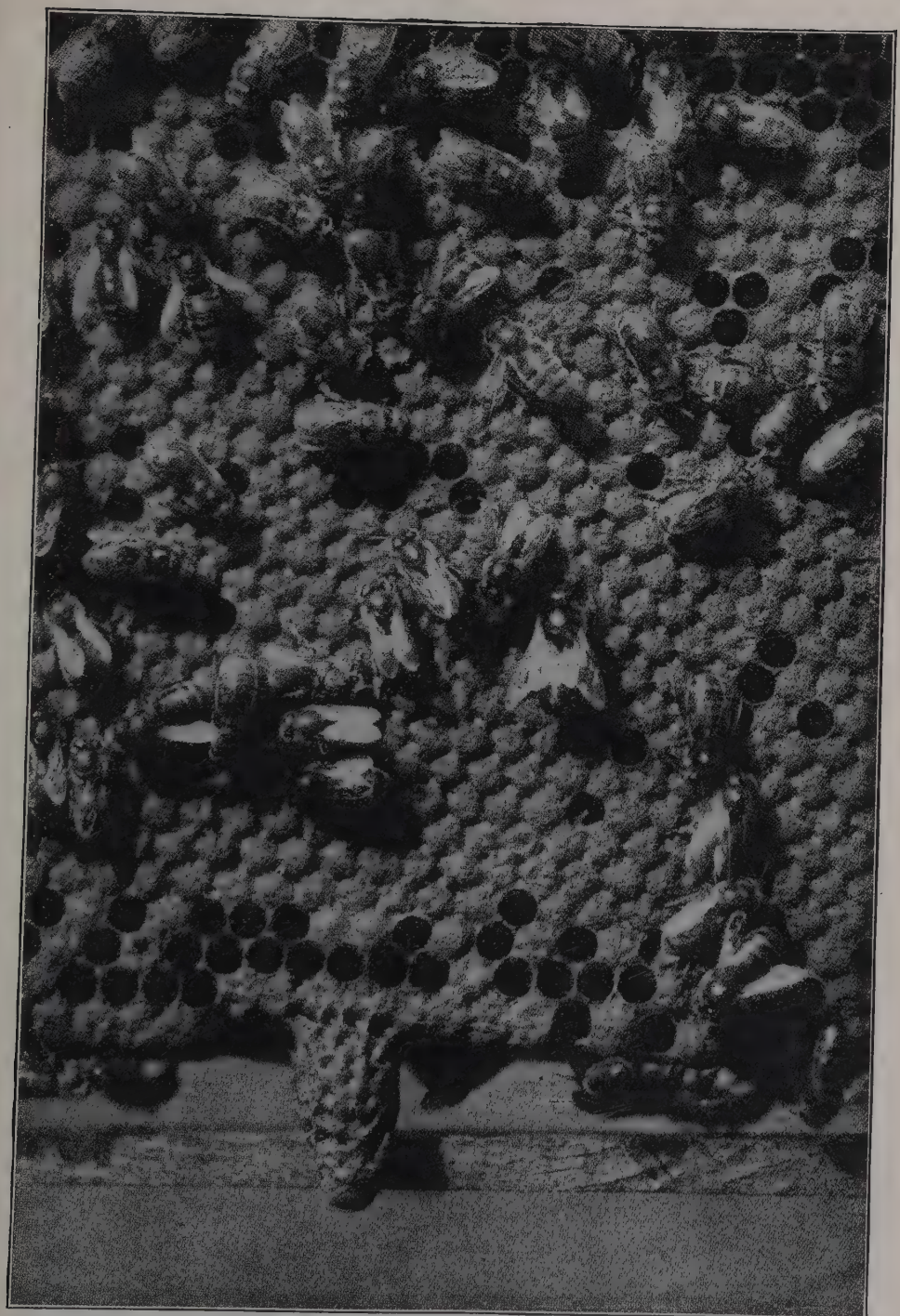
With the first warm days the bees come out and search for pollen and nectar, and the queen becomes active laying eggs. But the young must be fed regularly, and at this early date there is usually not enough nectar. Usually bees store enough honey in the summer to last them through the winter and spring until the flowers begin to produce nectar, but in commercial beekeeping we remove the surplus honey in the fall. If we fail to leave enough for the bees, their supply runs short and we must feed them in the spring.

The growth of a bee is quite fast. The queen lays one egg in each empty cell and this egg hatches in three days. As soon as the egg hatches, the workers begin to feed the tiny white larva or maggot first with "royal jelly," a secretion from the body of the worker bee, and later with beebread, which is a mixture of pollen and honey. With this rich food the larva grows rapidly, becoming full grown in five or six days. The cell is then capped over and the larva changes to the pupa in which stage it remains for about twelve days. At the end of twenty-one days after the egg is laid in the cell the adult bee issues. At first this young adult remains in the hive and does the "chores," such as cleaning out dirt and feeding the young. But after about two weeks of this apprenticeship, she flies to the field to gather nectar.

Every boy or girl would find it very interesting to study the wonders of a beehive. Only by watching the bees at work in the field and in the hive and by studying their habits will one understand and enjoy this marvelous insect. You will learn how the bee can gather pollen, how she learns to recognize the flowers which yield the most nectar, why bees swarm, why smoke is used to quiet bees in the hive, and the many other things which are never understood by the uninitiated.

Ants of many kinds

One of the most interesting republics in the world is that of the ants. The study of an ant colony shows how



A SECTION OF THE COMB OF A BEE

The queen bee deposits an egg in each cell in this comb. As the larvae hatch they are fed by the young workers until full grown, when the cell is capped over to form a cocoon within which the larva completes its changes. The cells producing queens are all constructed like the large cell at the bottom.

these little creatures work together, helping each other and even sacrificing for each other. All ants are of a social nature and live in communities. They even have castes and men who have studied carefully into ant habits tell us there are at least eight different castes. One caste is composed of the soldier ants, who have terrific battles and take other ants as slaves.

Did you ever watch ants going along their paths? They will travel rapidly in this way, but seem very much lost when taken off the path. Mark Twain has told us how he watched ants get hopelessly lost less than three feet from their homes.

Most of us think of the little red ant first. This one has become an unwelcome visitor in houses. Then there is the black ant and the white ant, which is not really a true ant at all. In the far West a queer honey ant is found. It goes to a certain kind of dwarf oak and there secures a sweet substance from galls on the tree. The honey ant will store up a quantity of this "honey," which really is grape sugar, and keep it in its abdomen to use in time of famine.

One trait of ants that is remarkable is their ability to recognize so many members of their own colony, and likewise their keenness in spying out a member of an enemy colony. When the enemy appears the ants are ready to fight.

The guests of ants are interesting. These include crickets, beetles, plant lice, mites and many others. Most striking among these are the ants' "cows," plant lice, which furnish a secretion or body juice from the digestive tracts that the ants like.

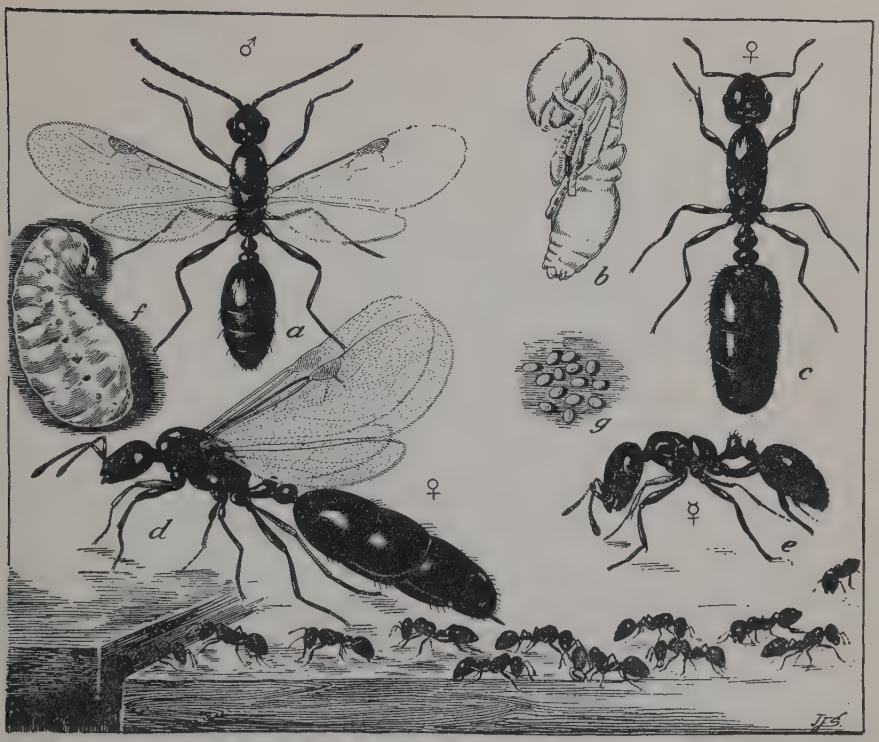
THE HALF-WINGED INSECTS OR TRUE BUGS

The true bugs include squash bugs, stink bugs, leaf hoppers, plant bugs, scale insects and aphids. They include a great many insects which differ in appearance and life histories. Aphids produce many generations each season, while the seventeen-year locust or cicada has only one generation every seventeen years. The plant bugs and leaf hoppers are quite active and go from plant to plant for food, but scale insects, once they attach themselves to a plant, must remain in that one place throughout their lives. But in two respects all of the true bugs are similar. All have incomplete development and all have sucking mouth parts. Also the majority are plant feeders and many are destructive to cultivated crops.

APHIDS—EXAMPLES OF TRUE BUGS

You have probably observed aphids or plant lice of one kind or another. The pale green ones on the stems of peas, the large red ones on golden glow, the black ones which occur on the terminal shoots of grapes or chrysanthemum or curl the leaves of apple, the gray ones on the undersides of cabbage leaves, or perhaps the greenish or grayish kinds on the roots of corn or aster. Some live fully exposed; others curl leaves and live within the protection of the leaves, and others produce deformities known as galls on leaves. A common gall-forming aphid is the one which produces the cockscomb-shaped galls on the leaves of elm.

Aphids are unusual in that the eggs may hatch in the body of the mother; they are born alive; also, during the summer months they grow very rapidly and begin to give birth to young in six or eight days. In other words, there are eighteen or twenty generations each year and each individual has a family of fifty to a hundred young, so you will understand why plant lice increase so rapidly, and sometimes become so abundant that they cover and destroy the plants. Like the other



U. S. D. A. Illus

ANTS

A colony of ants is like a large factory. We find several kinds of ants for special kinds of work and each group engaged in doing its particular work. The different stages of development are shown as: *g*, tiny white eggs; *f*, larva; *b*, pupa. In *a*, we see an adult winged male; *c* and *d*, wingless and winged females; *e*, worker.

plant bugs, they have incomplete development, and we do not find the remarkable changes as in butterflies and beetles. Instead, the young when it hatches resembles the adult except in size and development of the appendages.

Some insects depend on others for their existence and so it is in the case of aphids. The aphids are dependent on ants to take them from plant to plant and in many cases to care for the eggs during the winter months. Thus, we find the ants are very attentive to aphids and look after them as they would their own young. Why do the ants care for aphids? The reason is quite obvious when we know that aphids give off a sweetish fluid, which is in part the sap of the plant upon which it is feeding, and this fluid is much liked by ants. Because of this interesting feature of the life of an aphid they are often called "ant cows."

Insect Collecting

There is only one way to understand the wonders of insect life and that is to collect and study insects. Many have attempted to make a collection of insects but few have attained success, simply because they did not know where to collect the most interesting specimens, or how to mount them properly, or how to prevent museum pests from destroying their specimens after they had been mounted. Collecting insects is simple and fascinating, and the difficulties mentioned are easily overcome.

When to collect insects

Insects may be collected at any time of the year. During the winter many can be taken which may be difficult to secure at other times of the year and, furthermore, such collections give valuable information on how and where different insects pass the winter.

During spring, summer and fall there is an ever-changing insect world, just as one finds different flowers blooming at different seasons.

Where to collect insects

Search under and in logs, especially rotting logs, boards, bark of trees and such places. Leaf mold in woods yields many interesting species, and if leaves and other timber debris are collected and brought into a warm room the insects will become active and can be easily picked out. Shrubs along the roadside, in thickets and in the woods should be examined for cocoons from which fine specimens of moths will issue.

During the summer months insects are almost everywhere. Collections should be made at flowers and around lights and by sweeping vegetation with a net. Many of the less attractive caterpillars can be placed in cages of one kind or another, provided with the proper food, and reared to adulthood. The rearing of insects is one of the most fascinating phases of insect study, and also provides information on the different stages of development.

How to collect insects

An insect net should be used to collect butterflies, bees, wasps and flies, which will be found in abundance on flowers. Often these insects can be taken by turning the cyanide killing bottle over them. A net for sweeping should be of a heavier material than the thinner collecting net, as the sweeping back and forth through vegetation is likely to tear the fine net. Many interesting species may be collected at baits and traps. A mixture of brown sugar or strong molasses and vinegar, painted on trees or posts, will attract insects which fly during the day and also those which fly at night. A large fly trap baited with banana skins will attract others, especially moths.

Materials needed in collecting insects

In collecting there is needed a net to catch insects; a poison bottle to kill them; pins to pin them for the case; a spreading board to spread the wings of butterflies, moths and dragonflies, and a substantial box in which to keep the insects after they are collected, pinned and labeled. All of these materials can be obtained from one of the following: Ward's Natural Science Establishment, 302 North Goodman, Rochester, N. Y.; Kny-Scheerer Corporation, 508 Fifth Ave., New York, N. Y., or Central Scientific Co., 460 East Ohio St., Chicago, Ill. But some of the materials can be made by any boy or girl.

How to make an insect net

An insect net can be made by bending a four-foot piece of heavy galvanized wire (No. 3, 4 or 5) into a circle, leaving about three inches extra at each end. The ends are tightly twisted and inserted into a hole drilled in the end of a stick several feet long to be used as a handle. A tinner can make a tin cylinder and fasten it to the loop where the wires are twisted so that it will fit over the end of the handle. The bag or net should be made of cotton tulle, a good grade of cheesecloth, or, better, of bobinette. The net should be from 2 to 2½ feet long, and it will be more substantial if a narrow border of sheeting is stitched around the top, to cover the wire frame.

KILLING THE INSECTS

The insect should be handled carefully and killed quickly. Have two wide-mouth jars, a large one for butterflies and moths and a smaller one for plant bugs and beetles. Place from one-half to two ounces of sodium cyanide or potassium cyanide in the jar and cover the cyanide with sawdust or cotton. Place a half to a teaspoonful of water in the jar and fit over the sawdust or cotton two or three disks of blotting paper to hold the packing firmly in the bottom. Cyanide is a deadly poison and should be handled with the greatest of care. After handling cyanide, thoroughly wash the hands before placing them near the mouth. Mark the bottle "POISON" and keep out of reach of persons who do not know that it is poisonous.

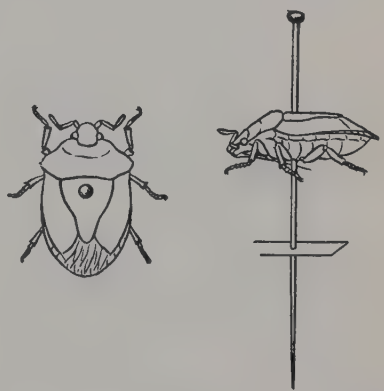
PINNING THE INSECTS

Specimens should, if possible, be removed from the bottle and pinned up within a few hours after collecting. Do not crowd the bottle with insects which are easily rubbed. Insects will pin easier if allowed to relax for fifteen to thirty minutes after being removed from the poison bottle. Butterflies, moths and dragon flies should be pinned through the thorax and spread as described below. Flies, bees, wasps, plant bugs and grasshoppers should be pinned through the thorax. Usually it is not necessary to spread the wings, but it is desirable to straighten out the legs with a pin or forceps. Beetles should be pinned through the right wing cover. For specimens too small to be pinned it is customary to prepare narrow, pointed triangles of stiff paper about one-fourth inch long, through the base of which a pin is run and upon the point of the triangle the little insect may be fastened with glue.

Common pins should not be used, for they rust and are too thick and short. Use special insect pins—No. 2 black pins for the small insects, and No. 3 black pins for most beetles and butterflies. A few of the large beetles and moths may require No. 4 or No. 5 pins.

SPREADING BUTTERFLIES AND MOTHS

To make a spreading board, use two strips of soft wood 18 inches long, 2 inches wide and ½ inch thick; one bottom board 18 inches long, 4¼ inches wide and ½ inch thick; three blocks 4¼ inches wide, ½ inch thick and ½ inch high; two thin strips of



U. S. D. A. Illus.

BUG
Illustrating method of pinning bugs.

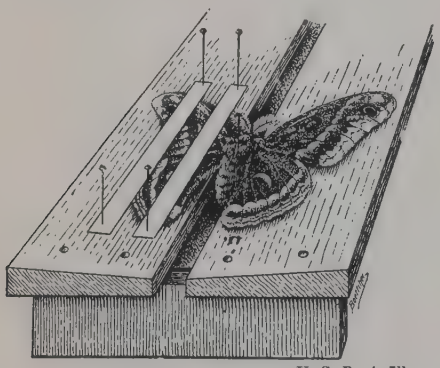
cork, 8 inches long, 1 inch wide. Fasten the two narrow strips of wood to the blocks, one at each end and one in the middle, setting the strips so as to leave a ¼ inch opening in the center. On the same side as the blocks, tack the pieces of cork, so that they cover the ¼-inch opening between the strips. The bottom board is then nailed to the blocks and the spreading board is ready for use.

The insect is pinned through the cork in the groove of the spreading board so that the wings, when spread, lie flat on the boards, the body fitting into the groove. Draw the forewings forward with a needle or fine pointed pin so that the rear margin of the two

wings is vertical with the body. Pin a strip of paper across the wings to hold them flat and in position and leave in a dry place for ten days or two weeks. Remove and place in the collection box.

Labeling insect specimens

Every insect collected should be neatly labeled with the town or county, state, date of collection, name of collector and conditions of capture, as "around light," "under bark," or "by sweeping."



U. S. D. A. Illus.

SPREADING BOARDS

Care should be taken in placing the strips across the wings, so as not to rub the scales from the wings.

An insect box

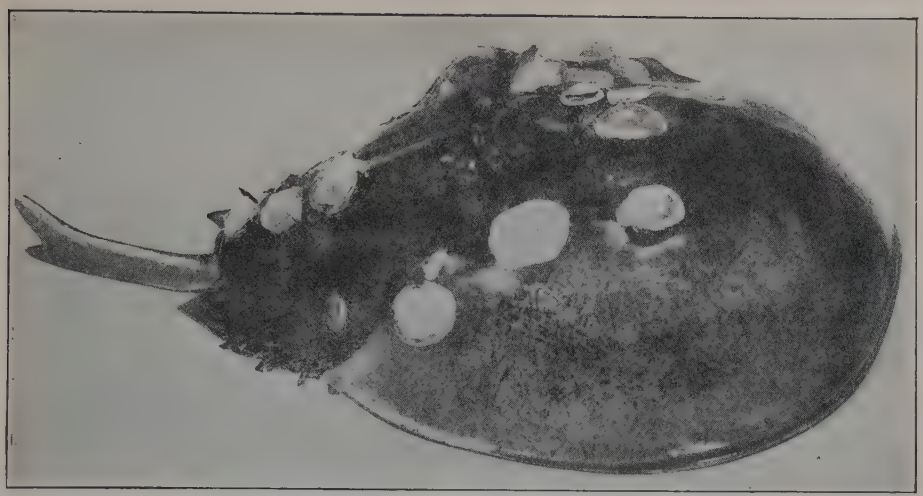
Cigar boxes lined with cork, slices of dried corn stalk pith or corrugated board are suitable as temporary boxes but not for permanent collections. For exhibition use a regular insect box, which can be made by any boy who is handy with tools. The standard insect box is a No. 2 Schmitt box with a patent cork lining, for sale by all dealers in insect supplies. A pasteboard insect box is satisfactory for temporary exhibition purposes, but has the disadvantage of being more exposed to museum pests.

Museum pests

Damage to pinned specimens by museum pests, oftentimes called dermestids, may be avoided by using proper precautions. Use tight boxes and examine occasionally. Moth balls are a convenient repellent. One can attach pins to moth balls so they can be pinned in the box. Heat the head of a pin and while it is hot thrust it into the moth ball. For boxes which do not have tight-fitting lids it is desirable to melt naphthalene flakes and pour a little of the melted material into the corners of the box.

If one finds any indication of dermestids, the box should be fumigated at once. Pour a half teaspoonful of carbon bisulphide on a piece of cotton in the box and close tightly. It is better to have a large, tight wooden box, in which the insect boxes may be placed for fumigation. On account of the odor of carbon bisulphide, treat the boxes in an out-of-the-way building or room. Do not have fire about when using carbon bisulphide.

Whoever attempts to collect insects should from the beginning try to secure perfect specimens, mount them in the best style, and secure as large a variety as possible. At the same time one should study them in the field to learn their habits. Having made the collection, one should learn from books and further observations more about the many interesting habits and the life histories of insects. Every day will bring the collector new facts, and with each new discovery the pleasure and interest will increase.



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HORSESHOE CRAB WITH LIVING OYSTERS ATTACHED

SOME OTHER INVERTEBRATES
OF LAND AND SEA

WHEN we think of invertebrates other than insects, we remember the spiders and scorpions, and then our thoughts must turn to the sea, where the lowly life of the world began.

There we discover many familiar "home bodies" such as the sponges and clams, that never stir from their moorings, and also the lively jellyfishes and crabs, that are free to go where they please. We dig in the wet sand at low tide, and perhaps bring up some sea worms—much prettier than our good friends, the earthworms. On the rocks, the barnacles and other little shelled creatures are waiting patiently for the tide to rise, and crawling on the bottom of the sea, starfishes and sea urchins and countless others spend most of their lives looking for something good to eat.

And so we find that myriads of animals without any backbone seem to be just as happy as those that have one.

Sponges

The sponges that are sold in drug stores are such familiar objects that we seldom stop to think that they are the skeletons of animals that once were living at the bottom of the sea. Some sponges live in water so shallow that a diver can go down and get them; others prefer great depths. A few species live in fresh water. It was centuries before these stationary bodies were even suspected of being animals, though wise old Aristotle guessed as much.

Sponges are of many kinds and shapes. Little ones, only an inch long, can be dredged off the ocean bottom near the New England coast, and others in the warmer oceans grow to be several feet high, and take the shape of vases—beautiful vases of the sea. One interesting variety, the deadman's finger sponge, rises from the ocean floor like a hand that points with many fingers.

Some sponges are soft, and others have tough skeletons, formed of many

little bodies, called spicules. These spicules are very interesting under the microscope, taking such shapes as clubs, arrows, anchors and mushrooms. Other sponges have a horny skeleton

GLASS SPONGE

A beautiful representative of a large group called "glass sponges" from their glassy fibers. (Photographed by L. B. Spencer, New York Zoölogical Society.)

without any spicules. There is one feature which all have in common: the way they get their food; all are supplied with certain canals, called incurrent and excurrent. The incurrent canals suck in water, the excurrent canals expel it—but only after all the food particles it contained have been held back for the sponge's dinner. Many little animals, such as crabs and shells and sea worms, live in the canals of the sponges, where they are out of the reach of their enemies. Sponges have few enemies other than man, for their odor, strongly resembling garlic, is apparently distasteful to fishes.

CORALS AND JELLYFISHES

Among the corals we sometimes find little colonies a few inches in diameter, like the northern white coral, that we collect in shallow water in the New York region, and there are the great formations of coral that rise mile-high and higher from the bottom of the sea until they make coral islands.

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PORTUGUESE MAN-OF-WAR

This animal is one of the common jellyfishes. It is shown feeding on an anchovy. (Photographed by L. L. Mowbray.)

It was a long time before people learned that coral is the skeleton of a

Courtesy N. Y. Zoölogical Society

A SEA MOUSE ON AN OYSTER SHELL

The sea mouse (SM) spends its life creeping about among the sunken gardens of the sea. This specimen in an aquarium was photographed by L. B. Spencer.

living animal—the coral polyp, a little animal something like a sea anemone. They fancied that coral polyps were "insects" that crawled in and out of their stony houses.

In the same group with the stationary corals are the sea anemones—beautiful "flowers of the sea," with tentacles that draw food to the mouth. In this group, also, are the jellyfishes, composed mostly of water, and of all sizes, from invisible forms to the great sea blubbers, that measure seven feet across, and have tentacles 100 feet long. Nothing in the sea is more delicate and beautiful than the jellyfishes and nothing can sting a bather more painfully, for the long tentacles are armed with poison cells.

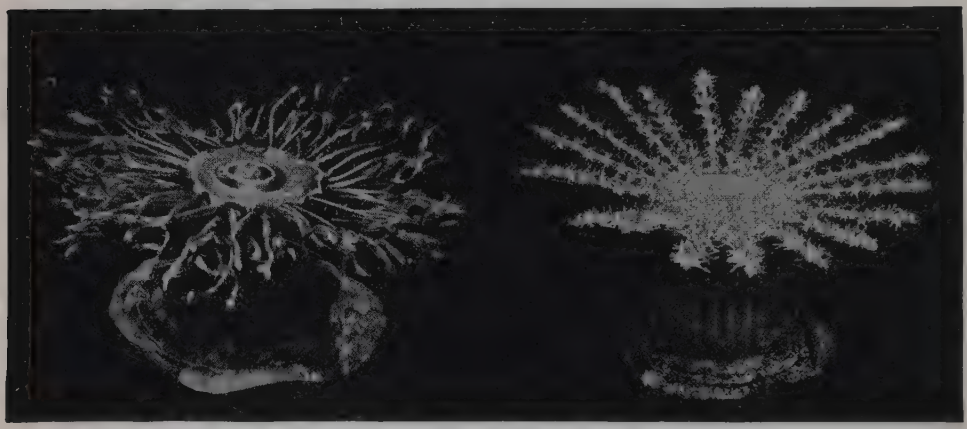
The Portuguese man-of-war, a common jellyfish in southern seas, captures many little fishes by paralyzing them with its poison tentacles, but there is one, the Portuguese man-of-war fish, that is immune to the poison, and lives under the float and among the tentacles of this jellyfish safe from its enemies, who dare not pursue it in its retreat for fear of being stung and eaten by its host.

Sea worms

Sea worms. That doesn't sound a bit fascinating. But truly, sea worms are among the most beautiful of all objects in the ocean. Some live in tubes and flourish gorgeous scarlet tentacles; others, such as the clam worm and the ribbon worm, swim near the bottom, or bury in the sand. Others, such as the arrow worms, live at the surface of the sea. A well-known variety, the palolo serves as human food. Palolos are found in both the Atlantic and Pacific Oceans. They are most appreciated by the Samoans and Fijians, and are considered a choice present for one chief to send to another. On two certain days of the year, when they approach the surface to spawn, the natives are ready, with boats and nets, to catch them. The worms are eaten alive, and are also baked in a kind of leaf sandwich.

TWO STARFISHES AND A SLUG

At the left is a brittle starfish; in the center, a big sea slug; at the right, a delicate feather starfish.



SEA ANEMONES

The anemone attaches itself to the shell inhabited by the crab (sometimes the crab places the anemone there to make its back look like a garden instead of like a live animal). The crab, moving about, takes the anemone to new feeding grounds. Anemones can move around themselves, but only very slowly.

SEA ANEMONES AND JELLYFISHES

In the center is a group of sea anemones which resemble flowers, but which hunt and kill. At the right is a single jellyfish; at the left, a colonial jellyfish.

The sea mouse, also, is a charming, iridescent creature—a worm that spends its life creeping about among the sunken gardens of the sea.

The sea does not contain all of the interesting aquatic worms, for many live in the ponds and lakes. There is the "wheel animalcule" or rotifer, unseen except with the microscope—a busy little creature with a whirling belt; and there are the planarians, or flatworms, with two little crescents for eyes, and beautiful scarlet worms, called *Tubifex*, all found in ponds and lakes.

Earthworms

Earthworms live in burrows, just beneath the surface of the soil. Here hundreds of them build their tube-like homes, largely by swallowing the earth as they dig down. This earth goes through their digestive tracts, and is then piled up near their doors in tiny piles, or "castings." The small bits of food are digested out; and the pulverized earth, from millions of these castings, forms, in time, a deep layer of surface soil which is ideal for grass and all sorts of growing things. In this way, earthworms are invaluable to man.

We know them chiefly, though, as "fishing worms," and for certain kinds of fish there is no better bait. Catching this bait is quite as good sport as the fishing which comes after. If you sprinkle a patch of sod or garden soil along toward sundown, and after dark go out with lantern or flash light, you will see the big earthworms or "night-crawlers" lying stretched half out their doors. Too much light will send them jerking back, for though they have no eyes, the head end senses light. A quick grab—and you have one by its head! Now don't pull—for if you do you'll have but half a worm. Its other half will go back under ground, and in due time grow for itself a new head end. Just wait a moment. Then if you are an old experienced hunter, you will give the worm a tiny pinch, and as it squirms, it will loosen, from the side walls of its burrow, its hundreds of bristly feet, and a quick pull will bring it up unbroken.

It is often said that earthworms "come down" in a hard rain—but they do just the opposite of that. They come up, to escape drowning in their burrows—much to the joy of the hungry robin family. Earthworm's eggs are laid, together with a milky fluid, in small cocoons from which the eggs hatch only when they are old enough to take care of themselves.

STARFISHES

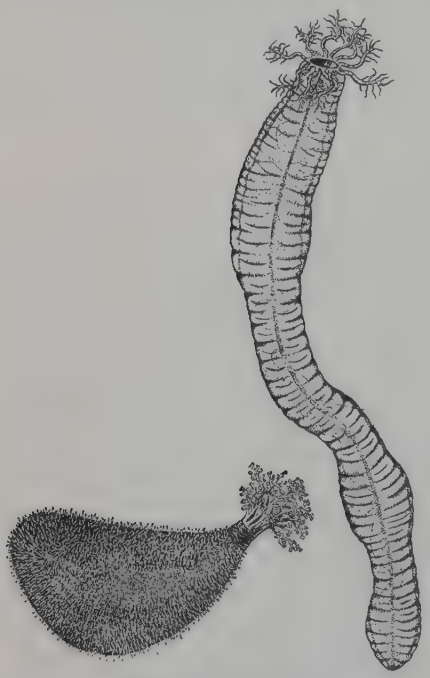
The one on the left is growing a new arm. It is just about to eat a mud snail.

Starfishes and their relatives, the sea urchins and sea cucumbers

Nearly everybody has seen starfishes—either alive or dried.

Their arms are fitted beneath with many suction disks, and their favorite food is mollusks, such as oysters, snails, clams and mussels. When the prey has a double shell, they force it to open

by pulling with their suction disks on opposite sides of the shell. After half an hour of steady pulling, the poor mollusk cannot hold itself shut any longer; and as it opens, the starfish turns its stomach inside out, introduces



SEA CUCUMBERS

These relatives of the starfishes are shaped something like cucumbers. (After Cole.)

it into the shell, and proceeds to the feast. Oyster growers and clam fishermen do not love the starfish, for often it reaches the prey before they do.

The starfishes are luckier than we are in one respect: if they lose an arm, they can grow a new one.

Some interesting relatives of the starfishes are the sea urchins, or sea hedgehogs, as they are more appropriately called, for, as they creep along—little brown balls with long spines sticking out all over their backs—they remind one of hedgehogs. Their cousins of the deeper waters, the sand dollars, are merely flat sea urchins with short spines.

Another interesting relative is the sea cucumber, which is shaped something like a cucumber with tentacles around the mouth. When the sea cucumber finds itself in unpleasant surroundings, or is disturbed by an enemy, it has the strange habit of casting out all of its organs—stomach, intestines, everything. Then, starting with practically nothing but its skin, it grows some new organs. Whether the sea cucumber does this to coax the enemy to eat its "innards" instead of itself, no one knows.

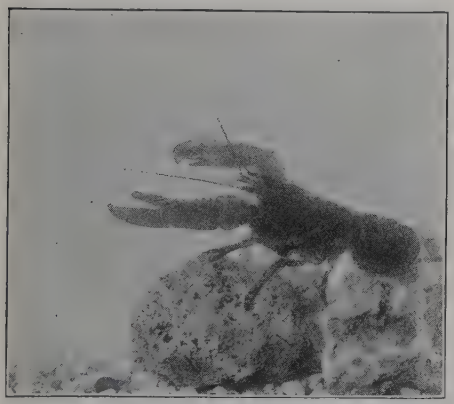
Lobsters and Crabs

We call the common, big-clawed lobster the American lobster, though we have other kinds in United States waters. There is the spiny lobster of the southern Atlantic and Pacific coasts, which has long feelers but no large claws, and which we sometimes call the "sea crawfish" just as we also call our inland-water crawfishes "freshwater lobsters," for the two are very much alike. There is also the locust lobster in waters of the tropical Atlantic, that looks more like a giant locust than a member of the lobster family.

The American lobster sometimes reaches a great size and weight. It may grow to be over three feet long and to weigh over thirty pounds—almost as big as a child except for its slender body. It is not always green, as you may have imagined, but is occasionally found with a beautiful blue shell, and one brownish lobster spotted with white is called the calico lobster. Sometimes, even, it is of a reddish hue, but this is so rare that when you see a red lobster you may be quite sure it is a boiled one. Lobsters and crabs and shrimps all turn red, as you know, when they are cooked. Once a clergyman referred to the lobster as "the cardinal of the sea," and people thought it a great joke be-

cause only boiled lobsters are red, as a rule.

The lobster lives in a burrow two feet deep, and as it is a cannibal, it snatches and eats other lobsters, and also crabs and little fishes that live near the sea-bottom.



Courtesy N. Y. Zoölogical Society

AMERICAN LOBSTER

The common big-clawed lobster may grow to be over three feet long and to weigh over thirty pounds.

The lobsters are rapid travelers. They leave the shore and go into deep water in the early winter, and some say they can cover twelve miles in three days.

Lobsters and crabs shed their shells many times in the course of their lives; that is the way they grow. The hard shell cannot grow, but the body underneath must grow, and so they cast their shells by drawing their bodies out of them, even to the eyes and the long, delicate feelers.

They become very timid at this time, and hide away among the crevices of the rocks, out of sight of their enemies, for a soft-shelled crab or a molting lobster makes a delicious morsel for any fish that may happen along. After a few days the new shell is grown—and lo!—the lobster or the crab is much larger than it was when it cast the old shell.

Barnacles

You will be surprised to hear that the barnacles which you see on rocks

Courtesy N. Y. Zoölogical Society

BARNACLES

Goose barnacles attached to floating timber. (Photographed by L. B. Spencer.)

at the sea shore when the tide is out, are related to the lobsters and crabs, even though they grow a much harder shell. If you could see a barnacle under water, you would find that the top of the shell opens when the animal feeds and a number of delicate, feathery little feet come out and kick the food into the mouth.

PERIPATUS

This strange and remarkable animal crawls like a caterpillar on its stumpy legs. It obtains food (such as ants and flies) by shooting glue from two ammunition pits, one on each side of the head. (From Shipley and MacBride, after Sedgwick.)

Peripatus

In that same group of "jointed legs" which includes the lobster, there occurs a very strange and remarkable animal which has no common name, so must be called by its proper scientific one, *Peripatus*. That it has no common name you will understand when you hear that it is found only in nine or ten places in the whole world, chiefly in Africa and Australia. This little animal is especially important because it shows, better than any other member of the family, a strong resemblance to its distant relatives, the worms.

Peripatus crawls around like a caterpillar on its stumpy legs, and defends itself and obtains food with two of the strangest weapons imaginable. These weapons may be compared to guns. They consist of two pits, one on each side of the head, in which, for ammunition, a quantity of sticky substance is made and stored. If *Peripatus* be excited, it shoots this glue sometimes a foot away. Some writers tell of flies and ants shot in this way, and say that while they lie, tangled and helpless, like flies on sticky fly paper, *Peripatus* crawls up and devours them at leisure.

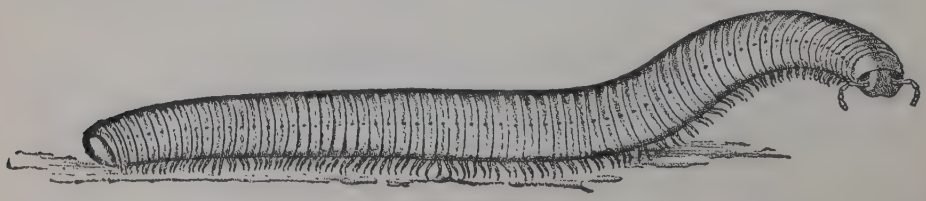
Millipedes and centipedes

Included in the group of "jointed legs" to which belong the thickly populated tribes of insects, are many other animals, not so well known, but just as interesting. Among these near relatives, we find the slow plodding "thousand leggers," better known as millipedes and their close cousins, the scurrying centipedes, or "hundred leggers." These animals are land forms, crawling on the ground or hiding in dark corners.

The millipedes prefer places that are moist and cool, but will venture forth over dusty roads and fields to forage for food. They are strict vegetarians, and are inoffensive creatures, except for the wire worm, which sometimes destroys our crops.

On the other hand, centipedes are found beneath the dead bark of logs, or in piles of dead leaves, and feed entirely on living animals. They are active, swift, and quite ferocious, and although in many ways they are bad-mannered, there is one thing of which they are often accused most unjustly. They do not crawl into people's ears.

There is a common centipede which has a hateful habit of appearing in our houses unannounced, and running on the floor or up the wall with such lightning speed as to strike terror to the bravest heart. This very animal is valuable to us, for it will eat flies, cockroaches and other insects; but in spite of that, no one can feel that it is a welcome household guest. If one should run across the floor, could YOU resist the impulse to cry out, "Step on it, hit it, kill it—quick!" And when you've killed a centipede, there is so little corpse! The long spidery legs roll up so tight, that you often wonder if, in your fright, you didn't see it many times its size. In the tropics, there are poisonous centipedes, often a foot in length.



MILLIPEDE

The millipedes or "thousand leggers," are land forms. They crawl on the ground or hide in dark corners. They are strict vegetarians. (From Shipley and MacBride, after Koch.)

A centipede may have its worm-like body divided into as many as one hundred and fifty tiny rings; and on each one of these, there will be found a pair of legs. This makes three hundred legs to keep going as it crawls. So, do you wonder that it has been said,

"A centipede was happy quite
Until a toad in fun
Said, 'Pray, which leg moves after which?'
This raised her doubts to such a pitch,
She fell exhausted in the ditch,
Not knowing how to run."

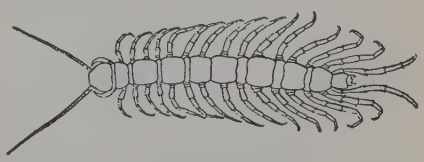
A millipede, when just newly hatched, has, as a rule, but three small pairs of legs, but as it grows, it adds them on and on, until it may have four hundred. These legs are fastened to the body rings as in the centipede, but on each ring we find not one, but two pairs. It is said that millipedes help to solve the problem of how to make so many legs go right, by moving them in groups of five. Even so, the number must appall them, for they never move with any speed.

A millipede lays her eggs in a nest in the ground. She burrows in the soil, and begins to moisten bits of earth with saliva. These she puts together into a hollow sphere, smooth within, and rough outside. She leaves a small hole in the top, and through this she lays her eggs. Sometimes she lays as many as a hundred in a nest, covered with a gluey fluid which makes them stick together. Lastly she makes a cover, seals the opening tightly, and leaves the eggs to hatch without further care.

A centipede lays fewer eggs, and does not prepare a nest for them. As she lays her eggs, one at a time, she rolls them in soft earth, until the gluey coating of the eggs picks up so much dust that the eggs can be left on top of the soil with no fear of discovery.

LAND SPIDERS

Have you always thought that spiders were insects? No, they're not, although they look like them. Count a spider's legs, and you will find it has eight—two more than the proper number for an insect. Get a "close-up" of its body, from the "waist-line" back. It is soft and rounded, and not divided into rings like that of grasshopper, bee, or butterfly. So we have to put the



CENTIPEDE

These animals are active, swift and quite ferocious. They are often called "hundred leggers." (From Shipley and MacBride.)

busy spiders in a class all by themselves, and we call them the Arachnida or "spinners." "But," you may truly say, "the silkworm caterpillar is an insect and a spinner." Here's the difference. The silkworm caterpillar draws its sticky thread from out its mouth; but spiders make their silk in special organs found at the extreme hind ends of their bodies. These organs, aptly named from what they do, we call the "spinnerettes." From them spiders send out at will a clear fluid, which, as it reaches the air, hardens or dries to form the silky web.

Among our most familiar spiders are the "orb" weavers. These trap their food in webs made by first crossing threads like spokes of a wheel, then winding round and round on this foundation, a gluey thread for tangling flies and other insects. So many angles and circles are there in this kind of web, that these spiders are sometimes called the "geometric spiders."

"Crab spiders" wear a dress to match the flowers they live on. Yellow and white—so near the color of petals or of pollen are they, that hungry bees and pollen eaters do not see them, and are caught and killed.

Large front legs these spiders have, so that they look like tiny crabs, and like crabs, too, they run sidewise.

Many spiders never use their silk for webs, traps or snares, but only to protect their eggs and line their shallow burrows. The big "wolf spider" is one of these. She wraps her eggs softly round and round until she has them wound in a large ball-like cocoon. This she fastens firmly to the end of her body, and goes about her daily tasks with her young brood bumping gently along behind her in their strange cradle. When these young spiders hatch, they mount on their mother's back, and from this safe place watch eagerly as she hunts for food. Alas for their good manners if she fails them! If she is unsuccessful, they fight among themselves, the strong, victorious, eating any of their small brothers and sisters weak enough to be vanquished in the fight.

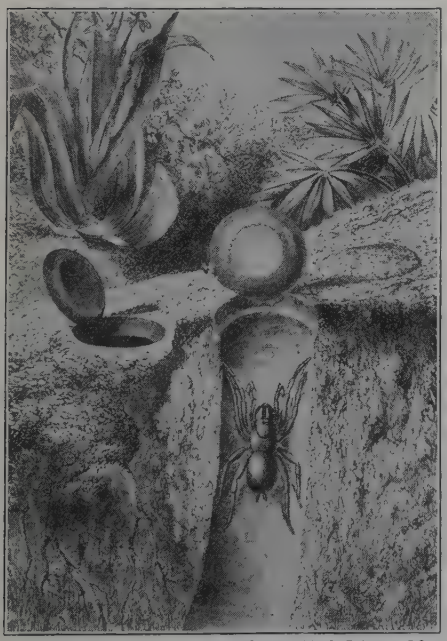
The "flying" spiders have no wings, and yet they travel through the air. How can this be? If your eyes are keen enough, you may find out some warm, bright, windy day. Young spiders seek a spot high above the ground, and there stand up on tiptoe, spinning as they stand. The wind catches the fine, soft thread, and gently pulls it out and out. Soon, there is enough thread flying in the wind to tug at the tiny creature, and, in another moment, to lift it free, and carry it, balloon-like, through the air. And so it travels away from home, where, perhaps, on account of so many in the family, food was getting scarce, until, winding up its silken sail bit by bit, the brave adven-

AN OFFERING TO THE SUN

Spider mother holding up her egg to the sun and turning it round and round. This remarkable photog raph was made by a French naturalist.

turer finds himself lowered gradually to earth in a new and unexplored land.

The trapdoor spiders are night prowlers, and by day hide in their small retreats behind doors made with great skill and cleverness. Two kinds of doors we find, one, circular, thin and wafer-like, hanging down like a flap, attached only at one side; the other made of alternate layers of silk



Am. Mus. of Natl. History Photo

TRAPDOOR SPIDER AND NEST

These night prowlers hide by day in their nests behind doors made with great skill.

and earth, thick, and fitted in as snugly as a cork or plug. The "cork" door has a patent lock—a notch to which the spider holds on tightly when she has gone inside and closed it after her. If "wafer" doors are used, the spider frequently builds another door farther down inside the burrow. This door opens inward, and the only way the spider has to lock it is by sitting close against it. Cork and wafer doors may both be hidden from our view by bits of moss or twigs stuck on them to make them look just like their surroundings.

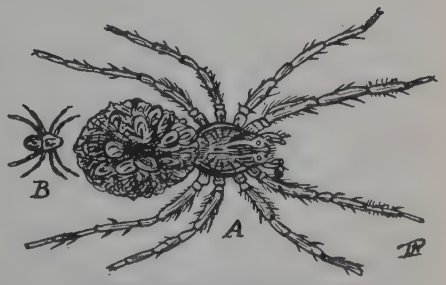
Spiders have many enemies. The solitary wasp carries off a spider to each one of her young. In the tropical

Am. Mus. of Natl. History Photo

FIND THE SPIDERS

Flower or crab spider on flowers.

countries, small monkeys eat them. Our dainty humming birds love to steal their webs to line their tiny nests, and some of them depend almost entirely on spiders for their food.



TAKING THE BABIES RIDING

The spider mother (A) is carrying the young on her abdomen. A baby spider is shown in (B).

WATER SPIDERS

Some spiders live in the water; and in Europe people sometimes keep the fresh-water spider in their homes in special aquariums, just to watch its interesting ways. The long hairs on its body catch a bubble of air at the

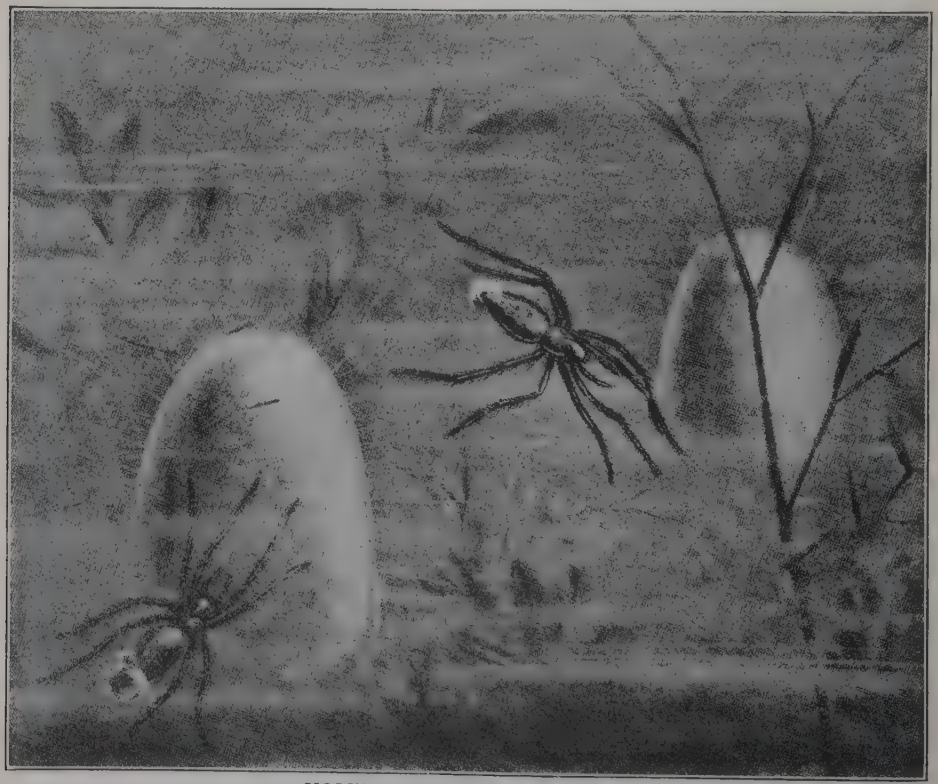
surface, and then it swims under water, breathing the air from its bubble. The air bubble looks just like quicksilver, and you can imagine that the spider is a pretty sight swimming about with its ball of quicksilver. It even builds a nest under water and fills it with air which it carries down in its hind legs! It carries bubble after bubble until the nest is full.

In the ocean are very tiny sea-spiders, which seem to be all legs. Some of them cling to the sea lettuce and live in the folds of its leaves along with many other interesting, invisible creatures.

A WATER SPIDER THAT TELLS A REMARKABLE STORY

The horseshoe crab is really not a crab at all, but a large water spider. Everybody who has visited the Atlantic seacoast has seen the cast shells of horseshoe crabs scattered about the beaches. They are thin and fragile, but much sought after for curio cabinets. If your eyes are sharp, you can sometimes find, in the sand, the baby horseshoes, just out of the egg, and if you have a magnifying glass you can see their shape, which is not like that of their parents. Instead, it resembles the ancient and long-extinct trilobite. This is regarded in the scientific world as positive proof that trilobites were the forefathers of horseshoe crabs.

Nowadays, trilobites are found in fossil rocks, where they were held fast millions of years ago when the rocks were hardening. These fossils also are much-coveted objects for curio collec-



HOME OF THE WATER SPIDER

These spiders build nests and live under the water. They catch bubbles of air at the surface of the water and carry bubble after bubble down to the nests to fill them.

tions. We know from the remains found in very old rock strata that the horseshoe crab as it exists today, has an ancestry dating back some seventy million years; and there is no other known animal that has retained its present form for that length of time. The horseshoe crab is not a highly intelligent creature, but it is hardy and it has managed to maintain its species throughout the ages, whereas many higher and more intelligent forms have perished forever from the face of the earth and the waters of the sea.

Horseshoe crabs are common on our Atlantic coast, all the way from Nova Scotia to Yucatan. Four species are found in Oriental waters. Live specimens have been shipped to California and also to Europe, but they do not seem able to establish themselves either in Pacific or European waters.

These interesting animals have several other names. They are called horsefoots and king crabs, and also Limulus. This last is their scientific name, but it is so pretty that many people like it best of all.

Generally it is the custom to pick up horseshoe crabs by the tail. If you lay one on its back, you will see the ten legs and the gills all working rapidly, for the horseshoe crab is just as active underneath as it is passive on top. The eyes are on the top of the shell and these inconspicuous little orbs, as you may guess, are not very powerful organs of vision.

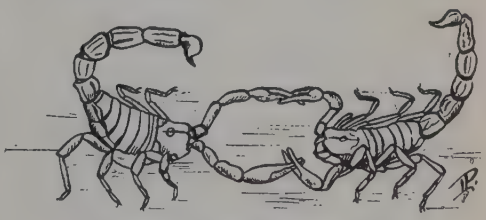
When the horseshoe crab is young and light, it often amuses itself by swimming upside down on the surface film, but when hungry it goes to the bottom to feed on clams and sea worms and other small animals picked up from the mud and sand. In captivity it will also eat fresh fish. It does very well in public aquariums, where flowing salt water can be provided for it, thus imitating its ocean home.

Limulus is so tenacious of life that it has been known to survive freezing and even to live a few days in fresh water. The eggs are as hardy as the animals themselves, for it is said that if they fail to hatch one summer, they may hatch the next. And it is also said that these baby horseshoes have eight years to grow ere they will reach the size of their parents.

Scorpions

The class Arachnida also includes the scorpions, spider-like animals with long, slender stinging tails curled high above their backs, poised for quick action.

Many terrible tales are told of their ferocity, but some of these are untrue. They do not, for example, kill and eat their young. In fact, their appetites are very poor, for even after sleeping and fasting the entire winter, they eat very little in April and May, when they again become active. They may also go for long periods without water, and therefore are the ideal settlers for dry or desert regions.



DANCE OF THE SCORPIONS

These spider-like animals carry their long, slender stinging tails curled high above their backs. (Adapted from Cambridge Natural History, after Fabre.)

It is often said that a scorpion, hard pressed by an enemy, will commit suicide by stinging itself. This also is untrue, for scorpion poison has been found to have no effect on the animal which made it.

Nevertheless, we must include the scorpions with the "criminal classes," for, after hiding in holes and crevices during the day, they prowl about by

night, stinging their close relatives, the spiders and insects, tearing them to pieces, and sucking out their juices.

THE OYSTER AND OTHER MOLLUSKS

An oyster is a very lively little thing when it is born. That doesn't sound possible, does it, when you think of the old oyster, which cannot move from its bed? Yet that is the way with the oysters and the clams. They are very active as babies; but when their shells begin to grow too heavy to carry around, they sink to the bottom of the sea and never swim any more. Now, it is different with the scallops, for they are light. They can clap their shells and swim. And it is different

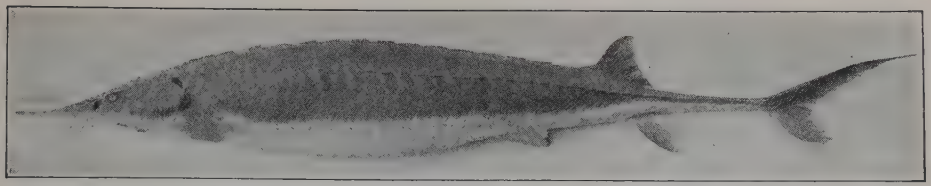
CHANNELED WHELK

One of the common sea snails. The animal is seen spawning a long string of eggs. It took eight days to spawn them all. Each little disk contains about 100 eggs. When the babies hatch they are just like their parents, only very tiny. (Photographed by L. B. Spencer, N. Y. Zoölogical Society.)

with the mussels, too. The fresh-water mussel plows through the mud with its strong foot. Time was when fresh-water mussels were very plentiful, but once in a while somebody finds a valuable pearl in one of them and then there is a raid on hundreds of mussel streams and lakes; but it is seldom that a pearl of much value is found in a mussel. The best pearls are taken from the pearl oysters. Then, again, the button manufacturers discovered what lovely pearl buttons can be made from the shells of fresh-water mussels, and they almost killed off the mussels in this country making them into buttons, so that the Government was obliged to interfere to save them. In the sea, the edible mussel also can move around. Its foot is not very strong, and it helps itself along by sending out sticky threads that fasten upon the rocks and act like arms to pull it along.

The mollusks with which we are all most familiar are the little land snails that we sometimes find in the woods, and the interesting water snails that we keep in our home aquariums. Some mollusks we hear a great deal about, but seldom see. These are the octopus, the cuttlefish (which has a remnant of a shell inside its body—the cuttlebone that we use in our canary cages), the squid, and the pearly nautilus. We have all heard exciting stories about the octopus, which some people call the devilfish, but there is a belief now that the octopus is not nearly so terrible as it has been pictured. Sailors seem to be more afraid of the giant squid, which may reach a length of twenty feet with arms thirty-five feet long. These arms, like those of the octopus and cuttlefish and pearly nautilus, are beset with suckers that can hold the prey tight and carry it to the horny beak. The beak is very strong, and can easily crush a big fish or a crab.

Sometimes the octopus is caught in an amusing manner. It loves to hide in crevices of rocks, and people take advantage of this habit by setting a jar on the ocean floor. The octopus goes into the jar to hide, and is drawn up, jar and all.



STURGEON *Field Museum of Natural History Photo*

FISHES

THE life of a baby sunfish is perilous indeed. Hatched from an egg with a "lunch basket" attached to its body—a sac containing enough nourishment for several days—the battle for existence is one round of excitement after another. Wherever the little creature goes it finds a host of water animals which seek to swallow it whole. Even those of its own kind are none too particular; most of them show no scruples.

There is little time for play. Every second that is not spent dodging enemies is devoted to hunting for food, for these baby fish have big appetites. In order that we may better understand, let us leave the sunfish darting about the sandy floor of the shallows for a few minutes and investigate this great tribe of water-breathing animals.

Fish are cold-blooded, shaped and equipped to live and move swiftly about in the water. They have a bony skeleton. They have gills which enable them to extract oxygen from the air dissolved in the water. Most fish have overlapping scales covering their skin. Many fish have air bladders to hold them up in the water and aid them in swimming. They have fins and tails for balancing, propelling and steering. Nearly all fish have teeth. They feel rather than hear sound waves.

THE FOUR CHIEF GROUPS OF THE FISHES

A simple though not altogether complete arrangement of the more common fishes by groups, from the

Courtesy American Forests and Forest Life

A SUCCESSFUL CATCH

*Scientific books on fishes differ in many ways, especially concerning minor details and classifications. Classifications of fishes based on anatomy and on supposed lines of development change rapidly as knowledge advances. The subject of structures and origins is a rapidly advancing branch of science. About 13,000 living species are now known, and there may be as many more not yet found out, not counting the prodigious numbers which have died out, leaving their bones in the rocks. This article will, therefore, be confined to a convenient, even if superficial, classification, and to some record of the most common and the more peculiar fish and their distinctions. —AUTHORS' NOTE.

lower to the higher forms, will help us to get better acquainted with them.

First we have the cartilaginous fishes. Sharks, rays and skates belong to this group which includes the fish with soft skeletons and usually minute tooth-like scales; some of the species are viviparous (pronounced vi-vip′-a-rus), which means born alive, the eggs being hatched in the body of the mother fish.

Next come the Ganoids (from a Greek word meaning "brightness"). The gar pike, bowfin, sturgeon and paddlefish belong to this group which includes many fish having armor-like scales or plates, and with the tail or caudal fin one-sided and turned upward behind.

Third are the bony fishes, an immense group of about 12,000 kinds, arranged in more than 100 families. Most fishes of the rivers as well as of the tropical seas belong to this group. Included in it are the pipefish, sea horse, eel, flatfish, catfish, sucker, minnow, balloonfish, flying fish, trout, salmon, pike and all the spiny-finned fishes, such as sunfish, bass, mackerel, tuna and swordfish.

Then, there are the lungfishes. These represent not the highest forms of fish life, but those nearest the higher vertebrates, and passing by degrees into the group of Amphibians —frogs and salamanders. They have partly developed lungs and the arm-bones in the breast fins show a resemblance to legs. The Australian lungfish and the South American mudfish represent this group. Others occur in Africa.

THE SUNFISH AND ITS HOME IN THE BROOK

Now let us go back to our sunfish sporting about in the shallows. Let us read the life history of this creature, for in habits and general appearances it illustrates the traits of a great many species of fishes.

Very quietly we approach a stream. We see a bed of clean bright pebbles. Over these a sunfish is poised. It darts away, then turns and watches us—on guard. It is a male protecting a nest of eggs. With a large spoon we carefully scoop up a few pebbles. Looking closely we see scores of tiny eggs between the smooth stones. Unlike most animals, it is the male fish, if any, which tends the nest of eggs, keeping away robbers. The male plays policeman until the young are hatched and have absorbed the contents of the food sac.

If we return to our stream in about a week, we see the small as well as the larger fishes make iridescent, flashing swoops as they pursue or are pursued in the battle of life. Hapless, indeed, the insect that falls in the water where these ever-hungry creatures are playing at catch as catch can.

Salmon and shad go up fresh water streams in spawning season to deposit their eggs often many miles from the sea. The salmon in Oregon and Alaska often ascend a thousand miles of river. Trout and suckers, too, ascend the streams they live in, sometimes making their way up tiny rills, almost into spring-houses to spawn.

Eels leave the streams of fresh water in the spawning season and travel far to sea where they lay their eggs in deep waters. The young eels, but a few inches in length, travel through several hundred miles of ocean to reach fresh water streams where they live until they are full grown.

THE FISH WITH SOFT SKELETONS—RAYS, SKATES AND SHARKS

The devilfish is the largest of all the rays, and a truly formidable crea-

SHARKS
Four sharks have been beached and the launch off-shore is out for the fifth.

ture, even as compared with many other sea monsters. Attaining a maximum size of more than twenty feet across the wings, in appearance somewhat like a giant water bat, there seems good reason for the name, "devil fish."

The sting ray is equipped on the base of the tail with a spine-like dagger, long, slender, sharply pointed and barbed like a saw along its two edges. The sting ray closely matches the color of the sand in which it likes partially to bury itself close to shore. It is found in most seas. Fortunately these vicious creatures live mainly in warm waters and do not often attack bathers. In the American tropics there are frequent cases of serious injury inflicted by sting rays on bathers and fishermen who stumble onto the unsuspecting fish or catch them in nets.

The sawfish, not to be confused with the swordfish, is armed with a long, flat, bony projection of the nose from both edges of which project a row of large teeth. This so-called "saw" is used mainly against schools of small fishes, as herring and anchovies, the fish swinging the saw from side to side by curving its body. In structure, the sawfish is between the ray and the shark.

Of about 160 species of sharks, only a few reach a great size. Those attaining a length of more than thirty feet are the basking shark, whale shark, man-eating or white shark and great tiger shark. The hammer-head shark, blue shark and thresher shark reach a length of more than fifteen feet. In general appearance sharks are not much unlike the typical fishes. Their scales are small and pointed, a circumstance which has occasioned the use of prepared shark-skin for centuries as polishing material for wood and other substances. The mouth is located more or less under the head and often is of immense proportion in comparison with the size of the fish. The teeth are large in proportion and grow in rows from the cartilaginous jaws, being continually replaced as new teeth push the old teeth outwards. The mouth is not pleasing in appearance, as the jaws are filled with a mass of teeth of different sizes and often of

Photographs on Pages 195, 199, 200 and lower picture on Page 201 by courtesy *Outdoor America*.

different forms placed at various angles.

The paddlefish, sturgeon and gar pike

The paddlefish is a scaleless fish of shark-like build, except for its bony-plated head which extends forward into a broad, bony paddle about a third the total length of the fish. It is found generally throughout the Mississippi Valley. It is valued as a food fish, and is often found in the markets. Sometimes it supplies the roe (eggs) for that excellent delicacy, caviar. The paddlefish is known to attain a weight of more than 150 pounds.

Sturgeon are prized, according to size, as highly desirable food fish. The mouth is underneath the head; the lips are long and sucker-like. It feeds along the muddy bottoms of deeper waters, sucking in mollusks and small, sluggish fish. Our lake sturgeon attains a weight of more than forty-five pounds. Specimens of the common sturgeon of the Atlantic coast are sometimes caught weighing more than 500 pounds. Sturgeon eggs in air-tight containers are commonly used as caviar.

The gar pike has an elaborate casing of diamond-shaped bony plates which gives it an armor-like protection second to nothing of the kind in nature. These polished plates, for all their size and strength, are so hinged together that they do not hinder the movements of the fish. Species of gar pike are widely distributed over the central and eastern part of the United States. Like the paddlefish, its snout is a bony extension; unlike the paddlefish, however, the lower jaw is also extended. Its long, slender jaws make it easy to identify. Another species, the alligator gar, has a shorter and broader snout. Both of these fish reach a length of more than six feet

Pipefishes and sea horses

Imagine a long, hollow tube of bone, jointed or hinged in sections, tapering gradually at one end and ending in a tiny tail fin, bulging at the other end into a head with a long snout for a mouth—such is the pipefish. A small fin is located midway on the back of this fish. A few more tiny fins assure us that it really is a fish, but at best do not seem to give it much swimming power. Its long, bony construction is its defense against other fish, for it is far too clumsy to escape an enemy.

As its name implies, the sea horse is an oddity that looks but little like a fish. It has a horse-shaped head and a tail adapted for grasping. It clings to seaweed with its tail and feeds on tiny crustaceans.

Fishes that look like snakes

Eels can easily and simply be described by merely noting their resemblance to snakes. They are scaleless, or their scales are very small and embedded in the skin, however, and, with their bony skeletons, must be placed with the large group of bony fishes.

The so-called "electric eel" of South America (not a true eel and not related to the eels) reaches a length of more than six feet and can produce a strong electric discharge to defend itself. Authorities who have experimented with this peculiar fish say that it is very dangerous to man. An electric shock has been given to every person occupying a small boat when the eel was hauled alongside after being impaled on a harpoon-like spear.

How the flatfishes got their name

The halibut is a typical representative of the flatfish—fishes that swim on one side. In the distant past the halibut was descended from some fish which swam upright in the water.

The young of all halibut and flounders swim upright when first hatched. Later the fish drops to one side and the lower eye passes around the front of the head or else through the skin. This flatfish trait became so pronounced that one eye has moved to the opposite side of the fish, by choice its upper side. In the very young there is an eye on each side and the body is vertical in the water, but the skull soon becomes twisted, bringing both eyes on one side. The upper side of this fish has also become colored to match the bottom of the ocean bed, and the lower side or belly which lies on the sand is a light color. Thus the fish is inconspicuous to its enemies. The flesh of the halibut is of fine flavor, as is the flesh of most of the flatfishes, known as flounders and soles.

THE FISH WITH WHISKERS

The fleshy, flexible barbels, called "whiskers," identify the catfish be yond any possibility of mistake. Each one of the thousand or more kinds has these appendages—four to eight in number. Incidentally these whiskers are very useful to the fish. They are sense organs and act as feelers. The catfish always swims about with its whiskers extended and waving until they touch something of interest, at which time they behave accordingly. It is easy to see that the fish has located its food by having touched it with these feelers.

The Mississippi catfish often weighs more than a hundred pounds. The channel catfish is a much smaller, more active fish with a preference for clear water. Its flesh, for this reason is more tasty. The commonest catfish

SEA HORSE AND PIPEFISH

One peculiarity of the sea horse is that the apex of the head is at an angle with the rest of the body. Its superficial resemblance to the knight of the chess board is striking. It is chiefly found in eel-grass or other vegetation and is wont to twist its very prehensile tail around some stalk and there remain in an upright position.

of the eastern United States is the bullhead or horned pout. It is a good food fish, though not regarded as aristocratic. None of the catfish have scales.

THE FISH THAT BUILDS A NEST LIKE A BARREL

The sticklebacks belong to the order of half-gilled fishes. They are especially interesting on account of

Courtesy Grassyfork Fisheries
JAPANESE FANTAIL
Goldfish are related to the carps.

their nest-building habits. They are small, voracious fish, living in brackish and fresh water.

The two-spined stickleback, so-called because of the two spines on its back in front of the back fin, attains a length of about six inches. It occurs in salty tidal waters and swamps along the coast. The male fish "spins" from his body a thread-like material with which he builds the nest wherein the female deposits her eggs. The finished nest, roughly barrel-shaped and open at the ends to permit the female to enter, is anchored to some stalks of vegetation. Immediately after the eggs are laid the female is driven off the nest by the male which fertilizes the eggs and guards the nest until the young are hatched.

THE FISH WITH SOLID JAWS

The globefish, the porcupine fish, the trigger fish and the trunkfish are all as odd as their names imply. They all have a solidified construction of the teeth and jawbones. Of far greater interest, however, are the peculiar shapes and external appearances of these fish.

The globefish, sometimes called balloonfish or puffer, when removed from the water, can pump air into its body, which swells like a balloon. If the fish is tossed back into the water in this condition it will float belly upwards for an instant before it suddenly expels the air, rights itself and swims out of sight.

The porcupine fish has the same power as the balloonfish to swell itself up, but in less degree. It is covered with erect, bony spines, sometimes an inch in length.

The trigger fish, found in tropical waters, is a thin, rough-skinned fish, sometimes brilliantly colored, with a bony spine atop its back, behind which is another trigger-shaped spine. The two spines can be rigidly locked together with the longer spine held up firmly in a position that frightens any larger fish that might try to swallow the trigger fish.

The trunkfish, or boxfish, is a triangular creature, built somewhat on the order of a box, its skin covered with large bony plates firmly bound together. Like most of the fish in this group it is found only in the warmer waters.

THE FLYING FISH

Many fish can leap far out of the water. Some can actually fly. The flying fish springs from the water and soars through the air, about four feet above the water, traveling in this way a distance of from twenty-five to fifty yards.

THE HANDSOME "SILVER KING"

A member of the shad and salmon group, the tarpon is remarkable for its great size. Covered with brilliant silvery scales, it well deserves its popu-

lar name of "Silver King." A large one (they are frequently caught weighing more than 300 pounds), caught on a hook, puts up a long and terrific fight before it becomes tired and can be hauled in.

SPECKLED TROUT
An attractive game and food fish.

Shad and Salmon

In years past the shad was a well-known and very popular market fish, but it has almost disappeared in many localities. It was caught only during the spawning season when it ascended the rivers and streams of the Atlantic Coast. The United States Bureau of Fisheries has introduced the shad to the Pacific Coast and has re-introduced it into many streams where it now far exceeds in numbers the yield of the Atlantic. It does not ascend streams very far. The shad is one of our most prolific fishes, one female having been known to deposit as many as 150,000 eggs.

The salmon, with five common species in the Pacific and one, very different from the others, in the Atlantic, is known the world over as a splendid food and game fish. The red salmon of Alaska is canned in enormous numbers and is the source of most of the American canned fish. Of great interest to the naturalist and angler is the ability some species of this fish possess to leap high in the air and over waterfalls sometimes twenty feet high that bar its progress to the spawning beds. (Read the story of the salmon in the article on "Canning" in the next volume.)

The Trout

This attractive game and food fish is well represented throughout North America by more than thirty native species, besides the brown trout which has been introduced to our waters from Europe. Of all the species, the brook trout of our eastern rivers is one of the most brilliantly colored. Its crimson and black blotches on a dark olive background are further set off by mottled back fins and crimson and white breast, belly and rear fins. The dark olive turns into pink along the sides, and underneath this band is a silver white coloration.

TARPON
This large fish is known as the "Silver King."

The Ferocious-Looking Pike, Pickerel, and Muskellunge

These fishes belong to a small order of one family with but five species. All look alike, with no front fin on their backs, with long, torpedo-shaped bod-

ies, large mouths, wide jaws of formidable appearance, large, slightly bulging eyes, and in general a ferocious attitude that is almost alligator-like.

Partly due to their hungry, greedy appearance they have been given the reputation of devouring any and all other fish they can capture. As a matter of fact they are as a group less destructive to other fish life than the black bass of the large mouth. When

MUSKELLUNGE
A thirty-five pound specimen.

a pickerel has its belly full, it is content to bask among the lily pads and let the angler's tempting bait pass by.

THE FISH THAT FIGHTS WITH A SWORD

This fish is always ready to introduce itself by means of its long, slender, sword-like appendage. Armed with a weapon about a third its length, the swordfish is dangerous even to the occupants of small boats in the vicinity when caught on a line by a hook or harpoon. Many occasions are on record in which the bottoms of boats have been cleanly penetrated by the swordfish. A section of oak planking, three inches thick and copper-sheathed, has been cut from the side of a ship in order to exhibit the sword of the swordfish

WHITE BASS
Found throughout the Great Lakes region and in the Mississippi Valley.

which was driven through it. This fish has been known to attain a weight of 575 pounds and a length of more than eleven feet, including a sword three feet seven inches long. The sword is used by the fish mainly to stir up schools of small fish, on which it feeds; it has no teeth.

THE FISH THAT GOES RIDING ON ANOTHER FISH

The remora which profits from the labors of others, deserves some mention because of the peculiar suction cap made from a modified fin and set atop its head by means of which it can attach itself firmly to the side of a larger fish. The remora is often found attached to sharks and other large fishes. The species range in length from six inches to about two feet.

THE TUNNY OR TUNA

The Pacific Ocean fish is called the "tuna," a Spanish name; the Atlantic fish the "tunny." On the Pacific Coast, especially near Santa Catalina Island,

YELLOW PERCH *Field Museum of Natural History Photo*

Found in eastern United States, abundant in the Great Lakes and in small lakes of the upper Mississippi Valley.

this large member of the mackerel family is eagerly sought by rod and reel fishermen as a fish worthy of their skill. Weighing anywhere from 100 to 500 pounds, and with all the energy that should go with such a weight, this big fish furnishes a spirited contest when hooked.

Recently, anglers along the Atlantic Coast have also caught this fish with rod and reel. Long known to the pound net fisherman as the "horse mackerel," the tunny has been on the eastern markets for more than a century.

THE PERCH

The small yellow perch, too well known to need a description, at least deserves mention if only for its popularity with the boy fisherman and for its fine flavor as pan fish. Despite its small size, it is a staple in some of the markets near the Great Lakes where it attains its greatest size and weight.

The yellow pike perch or wall-eyed pike is, of course, not related, except by a deceptive appearance, to the real pikes. This fish has a conspicuous front back fin, which, if you remember, the members of the pike family do not have. Pike perch weighing more than ten pounds are often caught. They are considered an interesting game fish, and find a ready place in the market as food.

TUNA

On the Pacific Coast, where this member of the mackerel family is abundant.

In tropical Asia there is a small perch-like fish which travels considerable distances overland in damp grass and climbs trees in search of insects.

The fish that almost has a lung

The bowfin, also called dogfish, mudfish, grindle and lawyer, is a coarse fish of the swamps and lakes. Its large air bladder is cellular, like a lung, and the fish uses it as a secondary organ of breathing. The flesh is rather soft and rank in flavor, and has but one virtue—it may be kept alive for some time.

It is a fish of unusual interest to the naturalist as it occupies a division of classification by itself. This is because of its air bladder which has cells and acts as a partially developed lung. The fish often breathes air at the surface of the water, somewhat as a frog might do just before submerging, and, if held below the surface, will sometimes struggle to reach the top as though it were smothering.

The bowfin attains a weight of about ten pounds. Its tail is rounded like a paddle. It may also be quickly recognized by the length of the back fin which extends from the base of the tail to about halfway up the length of the fish—a rather thin fin of almost uniform height.

Well named by reason of its lung-like development of the swimming bladder, the Australian lungfish breathes air in much the same manner as a reptile. Its gills are well developed and are used; the so-called "lung" is an additional breathing organ. Its breast and belly fins are long and somewhat leg-like—doubtless useful in crawling over the bottoms of the shallows.

In the Malay Peninsula is the jumping fish or mudskipper, which can hop over the mud flats with ease. The mudfish of South America has tiny, somewhat leg-like, thread-like breast and belly fins, and resembles a partly developed salamander.

Two strange groups of fishes

Sometimes fish are drawn up from great depths in the ocean equipped with a glowing light, which enables them to see in the dark depths in which they live. The lantern fishes are the commonest of these fishes which belong to several different groups.

Another oddity is the order of chimeras, or sea elephants, which resemble the sharks. They are not more than three feet in length and have a big head and a long slender tail. The chimeras are the descendants of a very ancient class of fishes, some of which were much larger than the living forms, of which there are about a dozen species, mostly of the deep seas.

A finny sportsman

Many unusual stories about fish have been discredited since scientists began to demand proof of alleged facts. Nevertheless, it seems to be established that there are fish which share with man the sporting instinct. These so-called "archers" are a group of small spiny-rayed fishes which are found in the waters of the East Indies.

In writing of the archer-fish, Sir Charles Bell says, "We have a curious instance of the precision of the eye and the adaptation of muscular action. The fish lives on smaller aquatic flies. When it observes a fly alighted on a twig, or flying over it—for it can shoot them on the wing—it darts a drop of water with so steady an aim as to bring the fly down into the water, when it falls an easy prey. It will hit a fly at the distance of from three to six feet.

BULL FROG *Field Mus. of Natl. Hist. Photo*

THE AMPHIBIANS

SPLASH! As you came to the edge of a brook or pond have you ever been startled by a frog diving hastily into the shallows? Did you know that toads drink water through their skins? Have you ever had the fun of catching little Yellow Stripe, the salamander?

ANIMALS THAT LIVE A "DOUBLE LIFE"

The frogs, the toads, and the salamanders are all cousins. Their other near relatives are the tree toads, the newts and the odd-looking mud puppy which is also known as the water dog or mud eel. They are an odd family. They all begin life in the water, but some of them, later, live on land or in trees. They are Amphibians (am-fib′-e-anz). The group name used to be Batrachian (ba-tray′-ke-an). This name means "frog-like." The Batrachians are now all included in the group Amphibia, a name meaning "double life," and referring to their ability to live on land or in the water.

These little, creeping, leaping, cold-blooded creatures (animals whose body temperature varies with that of the water or air in which they live are said to be cold-blooded) are divided into two classes: the tailless, containing the toads and the frogs, and the tailed, containing the salamanders, newts and the mud puppy. None is poisonous.

Almost every pool of fresh water throughout the United States is inhabited by one or more of the different members of this family. Watch the shallows of any clean pond on a quiet, warm spring or early summer day, and you will see what first appear to be dark colored pebbles with little tails swimming about the bottom. You will see one of the larger "pebbles" make a sudden dash for the surface. These pebbles are tadpoles, and they come to the surface to gulp in a bubble of fresh air. With a flip of their tails, they dive to the bottom again to resume their feeding. Tadpoles eat the slimes of the pools and are the best scavengers of stagnant water; they include dead animals and decaying plants in their diet. In turn, tadpoles are eaten by fish, snakes and water beetles.

In all the great outdoors, Mother Nature has few tales to tell which are more interesting than the story of these tadpoles which grow into frogs, toads and salamanders.

The story of the frog

In early spring the mother frog lays masses of tiny eggs, velvety black above, creamy white beneath. They number between five and six thousand, and are surrounded with a jelly-like substance which measures about five inches in diameter and two and a half inches in depth. The egg mass floats on the water and within a few hours the eggs begin to develop. After about nine days, the tiny black egg-specks have changed into queer little water animals called tadpoles, or polliwogs. They have no developed eyes, no mouths, nor limbs, but they have branching gills and long tails with which they swim. At first they breathe by means of gills (gills are organs that extract oxygen from the water). Their bodies look like roundish lumps of dark jelly. Soon a mouth develops. Then a wonderful thing happens—the gills disappear and the little creatures begin to breathe air instead of water, for a tiny pair of lungs has developed. When they rush to the surface for air, you may be sure gills have disappeared. Hind legs begin to grow, then front legs and teeth. Finally, tails grow smaller and disappear, and within two or three months we have a family of tiny, smooth-skinned frogs, keen of sight and hearing, fine swimmers and wonderful jumpers.

Frogs do not really "grow up" for three years, and they are supposed to live for from ten to fifteen years. Grown frogs live on insects, slugs and snails. Like toads, frogs often change their skins, eating the old skin as they pull it off over their heads. As with some other of her defenseless charges, Mother Nature has protected the frog from its enemies by giving it the power to change its color to match its surroundings; the frog can change from the green of the lily pads to the duller brown shades of the fallen leaves. This ability is called adaptive or protective coloration. It is fortunate that the frog possesses this ability for it enables it to escape from its natural enemies among the birds, fish, snakes and man. When you come to a pond you do not see any frogs unless your eyes are trained; the first knowledge you have that there are frogs about the pool is the sound of the splash they make when they dive into the water.

The best known frogs are the bullfrog, the spring peeper, the leopard frog, the "sticky toes" and the tree frog or tree toad.

Does it ever rain toads

Toads differ from frogs in that they have no teeth and are broader, flatter and darker in color.

Toad tadpoles are sometimes so numerous that we see what appears to be proof that it "rains toads." This is because so many tadpoles reach maturity at the same time. They have grown lungs and legs, and have left the water but are not quite ready to leave the moist banks of the ponds. A sudden rainstorm raises the water level, and the tiny toads scatter in all directions, an army of small brown dots, hopping into a new world in a rather bewildered manner. Small wonder that people used to believe that it "rained toads" when they stepped outdoors after a summer shower.

Spring peepers

One of the first sounds of spring is that of the spring peeper, a tiny frog that awakens with the first warm spell to fill the air with its plaintive trilling.

Listen for their *peep-peep-peep-peep* that comes from the ponds and swamps.

Try to approach near enough to see a spring peeper singing. Very few can come close enough to these little fellows without alarming them into silence; and when you do get close, they may slip out of sight under water, probably under the edge of a submerged leaf.

SPRING PEEPER

One of the first sounds of spring is the *peep-peep-peep-peep* of this shy little fellow.

Try to catch one of these little fellows. As you approach the boggy piece of ground the peepers become quiet. Stand perfectly still for a short time on a tussock of swamp grass. In a little while you will hear one begin to *peep*, then another and another until you are surrounded by the sound. Do not move. Keep your eyes open. Soon you will see a slight disturbance in the water close by. A tiny frog will climb up on a leaf or large blade of grass. Its throat will swell out like a white bubble as it joins in the chorus. Reach quickly, but grasp gently, or you will crush this little fellow, that, for all the noise it can make, is no larger than the end of your little finger.

The spring peeper is one of the smallest of our frogs and belongs to the tree toad family. It is well named "spring peeper" as its voice is sometimes heard before the first violet blooms.

Catch one and examine the tiny disks on each toe. These disks identify the tree toads. Let one cling to your finger. Then turn your finger down, and watch how the "sticky toes" are used by the frog in turning about so that its head will be again in an upright position.

Tree Toads

When the violets are full blown and the peeper's voice is seldom heard, it is time to look for the acrobat of the frog world, the common tree toad.

Am. Mus. of Natl. Hist. Photo

GRAY TREE TOAD

This toad changes its color to match the surroundings.

This tree toad never hesitates to leap in any direction after a fly, trusting to luck for a safe landing on another leaf or twig. Its toes are claw-shaped and have knobs on the tips which exude a sticky fluid. Like all frogs and toads, tree toads are useful as destroyers of insects.

It takes sharp eyes to see this little fellow, for the tree toad changes its color to match its surroundings. On

a leaf you may find one colored almost any shade of green. Place it on a piece of gray bark and soon you will see a gray toad.

Several explanations have been offered for this ability to change color. The most logical explanation seems to be that the color in the skin is really a liquid and the shades of green, gray or brown flow from an under skin (which acts as a color reservoir), into the outer skin which displays any one of these shades that most closely matches the surface the toad is on.

COMMON TOAD

The toad has no jewel in its head, but it does have a beautiful glittering golden eye.

Toads drink through their skins, and probably absorb water from the moist earth they burrow into, as well as from the rain puddle in which they are often seen.

Nature has given the toad a weapon that can be used for defense. A mild irritant is secreted in the skin. When alarmed this fluid is sometimes discharged over the body. In addition to this the toad has been given a color and a rough, bumpy skin that closely matches the earth.

In years gone by it was generally believed that the toad had a jewel in its head, and many of these harmless, inoffensive little creatures were killed by would-be treasure hunters. The toad has no jewel, but it does have a beautiful glittering golden eye.

It eats only live prey which it snatches with its sticky tongue. It is said that a toad is worth five dollars a year for destruction of cutworms alone. A toad will devour a hundred rose beetles or fifty cutworms at a meal.

Newts and Salamanders

The red spotted newt is about four inches long. It is a lively, frolicsome and attractively colored little creature. Swarms of them may be found in many ponds and lakes in the spring and early summer, when they live almost entirely in the water. Some species live in water entirely and never lose their gills; others take to land and are found in moist, cool places. Newts cast their skins and are said to replace lost limbs.

Tiny water insects, very small tadpoles and many small bugs that drop to the pond's surface furnish food for the newts. Newts' eggs are wrapped carefully, one at a time, in the leaves of water plants. It takes newts four years to "grow up," when they return to the water to breed. While they are in the water they breathe through the skin, the lungs not being used.

Salamanders usually live under stones and logs in damp places. They lead an uninteresting existence, though many of them are beautifully colored and will reward you with the thrill of discovery when you unexpectedly expose them to the sunlight by turning over a log or stone along the edge of the brook.

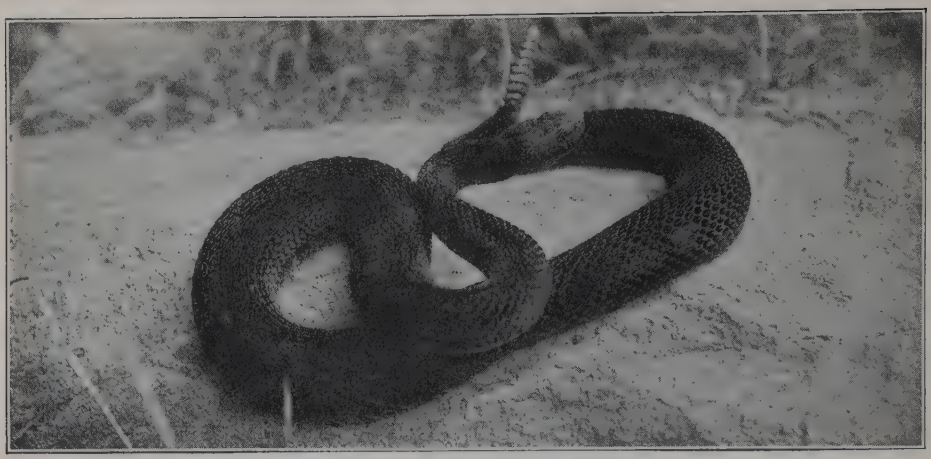
Salamanders and newts resemble lizards, having elongated bodies and four sprawling legs. Sometimes baby salamanders are born alive and sometimes they hatch from eggs. The giant salamander of China lives entirely in the water and has both lungs and gills.

WATER NEWT *Am. Mus. of Natl. Hist. Photo*

GRAY-BACKED SALAMANDER *Am. Mus. of Natl. Hist. Photo*

Some salamanders live in dark caves; they have no eyes and are white. There are many varieties. They live on snails, worms and insects.

The mud puppy is a salamander about a foot long, dirty brown in color, with an eel-like body and two short legs under the head. Never leaving the water, it spends its days among weeds and rocks in the mud. At night it moves quickly about hunting crawfish, bugs and worms.



BLACK-BANDED RATTLESNAKE

REPTILES

"LOOK out! There's a puff adder. Hear it hiss. See how it's coiled—ready to throw its head forward and sting you."

All this and much more has been said about the hognose snake, variously known as sand viper, puff adder, blowing adder and checkered adder. As a matter of fact, this little puffed up reptile never attempts to do more than frighten its tormentor. It can be picked up with perfect safety while it is hissing and striking. It never bites. It is a bluffer. Its only means of protection are a hiss, a dangerous appearance and a pugnacious attitude. Sometimes, when these fail to frighten off the tormentor, the snake will play dead, lying on its back with mouth open.

All our reptiles are shy and prefer escape to battle. But no snake is a coward. Reptiles do not sting. They bite; their teeth are small and sharp. Poisonous snakes have two long, curved fangs which inflict a wound into which venom is injected.

Man is just beginning to get acquainted with snakes. For years people killed snakes on sight. Now we know that many of these legless creatures are our friends. Take, for instance, the long, slender green snake —it is exceedingly fond of the hairless caterpillar, the kind that does so much damage in the garden. A great many snakes eat mice and rats and other rodents that cause loss and spread disease. Snakes are our valuable allies.

THE POISONOUS SNAKES AND HOW TO KNOW THEM

There are but four kinds of poisonous snakes in the United States: rattlesnakes, the copperhead, the water moccasin and the coral snakes. When we are able to recognize these we can approach any of the others without fear.

Little need be said about the rattlesnake. The various species are quickly identified by the rattle. A dangerous rattler is the large diamond back, which is found from South Carolina to Florida, and in the Southwest. Other kinds of rattlesnakes are found in almost every part of the United States. These snakes do not always sound the rattle before striking. The number of

rattles does not indicate the age of the snake. Rattlesnakes are valuable as destroyers of rodent pests.

The copperhead, sometimes called land moccasin, gives no warning of its presence. This snake will glide away as one approaches it, and seldom, if ever, will attack unless it is teased with a stick or accidentally stepped on. It is small, usually less than four feet in length. The copperhead is likely to be found anywhere in the eastern states, west to Illinois, north to Massachusetts, south to Florida, and southwest to the Rio Grande River. It is hazel brown, the pattern, when viewed from above, resembling a series of saddles or hourglasses. The head is distinct from the neck. It lives chiefly on mice.

The water moccasin, or cottonmouth snake, is a big, thick-bodied, dangerous reptile, often growing to a length of five feet. It is found in swamps, creeks and rivers from Florida to North Carolina, to Texas, and as far north as Illinois and Indiana. The moccasin is often seen basking on bushes along the edges of streams and swamps. When suddenly confronted, a short distance from water, it will usually draw the head back with mouth open and fangs erect ready to strike. When met near water, it will usually plunge in and swim to a hiding place. It is a dull olive green with head distinct from the neck. It lives chiefly on fish, frogs, and other cold-blooded creatures.

The coral snakes, small and not numerous, are brilliantly banded with broad rings of black and scarlet, separated by narrow rings of yellow. They range from North Carolina south to the Gulf of Mexico and west through Texas to Mexico. The coral snakes usually live underground and are seldom seen. They are short-fanged serpents, relatives of the cobras of the Old World.

The fangs of the snake

The venoms or poisons of the rattlesnakes, the copperhead and the moccasin are much alike. These snakes are cousins. Venom comes from glands behind the eyes and is conducted to the fangs in the front of the upper jaw by tubes or ducts. Muscles contract about the glands and force the venom through the two hollow fangs as the snake strikes. A poisonous snake can-

COPPERHEAD
One of our commonest poisonous snakes.

not leap off the ground. It cannot strike more than half its length. The hypodermic needle was patterned after the snake's fang. The fangs are replaced about as often as the snake sheds its skin. The fangs, when old, are embedded in the body of prey and swallowed. They are so hard that the snake cannot digest them, though the stomach juices digest the teeth, claws and bones of the animals eaten. Behind each active fang are several other fangs in various stages of growth. When the active fangs are shed the two immediately behind them slip into place and become active.

The first thing to do when a person is bitten by a poisonous snake is to wind one or two bands between the

wound and the heart. Then enlarge the fang punctures and promote bleeding, washing the wounds with a permanganate of potash solution. Antivenine should be injected into the back and the victim hurried to a doctor. If treatment is prompt, recovery is almost certain. Few people die of snake bite in this country, but in South America and in Asia thousands die from this cause each year.

How snakes travel and the fable of the hoop snake

A snake moves in one of two ways. It may "swim" over the ground, with alternate thrusts forward, first from one side, then the other, its head weaving from side to side as it puts its body in place for these continuous thrusts, taking advantage of irregularities in the ground, stones and twigs, to give it support against which to shove itself forward. It may move very slowly forward, with no side thrusts, the many plates on its belly giving it, in a way, almost as many "legs" as a centipede. These plates slide over each other in a rippling motion from the neck to the tail, the outer edge of each pushing against the ground, then being pulled in and forward to be placed again on the ground a fraction of an inch ahead of the spot from which it was withdrawn.

Snakes are cool, dry and firm to the touch. Some are rough-scaled, others are smooth-scaled. They have no eyelids—a rapid motion will awaken a sleeping snake. They have no external ears and do not hear very well. The forked tongue is a harmless, very delicate feeler, a sense organ we do not fully understand. It helps the senses of sight, smell and touch. It is believed that by it the snake receives vibrations. Perhaps one reason why we seldom see snakes is because the feelers, acting like little antennae on a radio equipment, receive the vibrations caused by our tramping and advise the snake to seek shelter. If this tongue is pulled out, the snake dies. Snakes cast their skins several times a year, working them loose around the mouth and then crawling out of them; the eyes take on a bluish cast when the snake is about to shed. The upper and lower jaws are not hinged tightly together. This condition allows the jaws to stretch wide apart so large prey can be swallowed. Snakes do not chew, but swallow mice, rats or other prey whole.

The "hoop" snake exists only in imagination. No snake can put its tail in its mouth and roll down hill; to do so would break its back, even if it could maintain its balance. Many black snakes, racers and whip snakes in squirming frantically down a steep hill will occasionally "stumble" and appear to turn a somersault, their tails flying through the air. It is possible that from such a sight originated the fable of the "hoop" snake.

Getting acquainted with harmless snakes

The garter snakes include most of the striped snakes colored yellow, green and red. They are found almost everywhere in the United States. Their food consists chiefly of insects, toads and small frogs.

The water snakes found in the United States are usually marked with bands, though the striped water snake has no bands. Most water snakes feed on fish and frogs or smaller snakes.

The ring-necked snakes and dozens of other small, burrowing snakes, living mostly on insects, are of little interest.

Of the many snakes found in North America, those most useful to us by reason of their fondness for rats and mice are the fox snake, pilot, or mountain black snake, chicken snake, corn snake, pine snake, gray rat snake, bull snake, black racer, indigo snake,

coachwhip snake, blue racer, striped racer and the king snakes.

The whip snakes, black snakes, racers and indigo snakes are very agile and travel swiftly through thick underbush.

BLACK RACER
Very fast, nervous, a good rodent destroyer, harmless

The king snakes and most of the others are constrictors that kill their prey by winding coils about their victims and crushing them lifeless. Some snakes are cannibals, including the king snakes, which cannot be poisoned by the poison of other snakes. No one knows just what gives these snakes this quality.

Snakes do not mate for life. Some varieties lay eggs which have tough, leathery shells and grow larger as the tiny snake within each develops; other species bring forth living young. A litter will contain from ten to forty young. The young snakes do not long remain with the mother snake.

A snake may fast for several weeks and then gorge itself with food. An indigo snake, pine snake or bull snake may eat a dozen mice at a meal. Snakes prowl in the burrows of rodents and wipe out whole families of these pests at one time. Rodents such as rats and gophers eat their own weight in grain or other food each day. They destroy hundreds of millions of dollars worth of property each year; by gnawing matches and wires they cause fires; their burrows break down irrigation dams and ditches; the dirt mounds they make injure harvesting machines; they spread disease by carrying germs. Hunting and trapping have so reduced the number of skunks, foxes, birds and other rodent enemies that nature's balance of rodent control has been disturbed. Consequently, the importance of the snake as a rodent destroyer increases each year. Rodent-eating snakes are too valuable to kill.

The speedy lizards

Have you ever tried to catch a pine lizard or a swift with your hands? Most lizards, swifts and race runners are exceedingly quick in their movements. Sometimes newts and salamanders are confused with lizards, but the latter may be identified by their scales.

A DAY WITH KING SNAKES
The author of this article is holding seven kings by their tails. These useful snakes are harmless.

Nearly all lizards are hatched from eggs. Unlike the snakes, the lizards have eyelids.

With the exception of the gila (*hee'-la*) monster, found in the Southwest, lizards are harmless. In some

places, especially in the Southern States, they are so numerous that it is not unusual to see them on the screen doors and windows of houses and hotels, even in the larger towns and cities. Lizards feed almost wholly on insects and consume great quantities of flies and mosquitoes. A lizard will jump after a fly many inches away, and catch it before it takes alarm.

Courtesy N. Y. Zoölogical Society

CHAMELEON

This little lizard can change its color. It usually chooses a shade that matches its surroundings. This one is climbing an ivy vine.

Lizards cannot inflict very painful wounds; those up to six inches in length seldom have teeth long enough to pierce the skin of your hand. Some species grow to seven feet in length. Many species possess the power of snapping off the tail if it is seized.

Many of our lizards are beautifully colored. Some will make themselves at home in a small cage and eat mealworms or tiny bits of meat, flies and other insects. The squirrel-like agility of lizards in a pile of twigs, their quick leaps after insects, and the occasional "stalk" they indulge in to creep within reach of a winged insect will entertain you if you will take the time to watch them.

The chameleon is a lizard that can change its color from green to gray or brown and back again. Nearly always it chooses a shade that matches closely the tree trunk or leaf to which it may be clinging. This little creature is caught in large numbers and shipped to pet stores throughout the United States. It makes an unusually attractive and interesting pet.

Among the lizards there are many interesting individuals; they do many odd things, and we do not know why. Take, for example, the horned toad, which is really a lizard. This strange little animal will, when disturbed, squirt little jets of blood first from one eye and then from the other. Whether it does this because it is frightened, because it hopes to frighten its tormentor, or for some other reason, we do not know. Then there is the iguana—a true lizard that, unlike its relatives, eats fruit rather than meat, lives in hollow trees, rather than on the ground, and seeks safety under water, rather than underground. Perhaps it is the exception that proves the rule. The flesh of the iguana tastes something like chicken, and is highly valued. Another interesting though repulsive lizard is the gecko, which takes its name from the peculiar cry which it utters. This little fellow has "sticky" feet which enable it to walk on smooth surfaces.

THE TALE OF THE TURTLES

Turtle is the general name for a group of fresh and salt water reptiles. Tortoise is properly applied to land

Courtesy N. Y. Zoölogical Society

ALLIGATOR TURTLE

This large and greedy snapping turtle is found in rivers of the Southern States. It is edible. It differs from the common snapping turtle in its greater size and scaly head.

forms. Turtle eggs are usually deposited in holes in sandy banks, covered with sand, and left to hatch by the heat of the sun. The young begin to crawl as soon as they emerge from the eggs, and quickly find their way to the water. Turtles have no teeth, but the jaws are edged with tough, horny skin. The tortoise shell of commerce comes from the hawksbill turtle.

Of our many turtles, the snapper is perhaps the best known. This vicious fellow is found in nearly every river and lake in the United States. The snapping turtle is well named. It has a parrot-like mouth, a pair of powerful jaws and a long neck. It can throw its strong "beak," sharp as a pair of scissors, forward with its rubber-like neck, and, should it clamp on your finger, you would carry a scar for life. Stewed snapper and snapper soup are considered tasty foods by many people, and perhaps the snapping turtle is of some value to us for this reason.

Snapping turtles, and almost all turtles that have a soft shell or small lower shell that is partly soft, live almost entirely in the water, are scavengers, and forage the muddy bottoms for frogs, tadpoles, sluggish fish and insects. The snapper occasionally basks on the bank or on a floating log. The long-necked soft-shelled turtle is very seldom found out of the water. The flesh and eggs of the green turtle are prized as food, as is the terrapin.

Most pond and creek turtles have an almost flat upper and lower shell. Both shells are firm and are frequently brightly colored. These pond turtles, such as the yellowbelly, slider, painted turtle, spotted brook turtle, and terrapin are very active in the water and more or less at home in swampy spots and along the shores of streams and lakes. They frequently leave the water for fruit, nuts, insects and even mushrooms, though they live mostly in the creeks and ponds and prey on water creatures they find under the surface.

The swamps usually have a full quota of turtles. Here the many tiny pools and thick foliage offer a safe retreat and food is not too difficult for such clumsy creatures to catch. As the weather gets warm—about the time violets are plentiful—the tussocks of swamp grass are used by the swamp turtles every sunny morning as resting

places on which they can bask in the sun. In the hot afternoon you will not see many of them as they are then foraging for food in the mud and weeds.

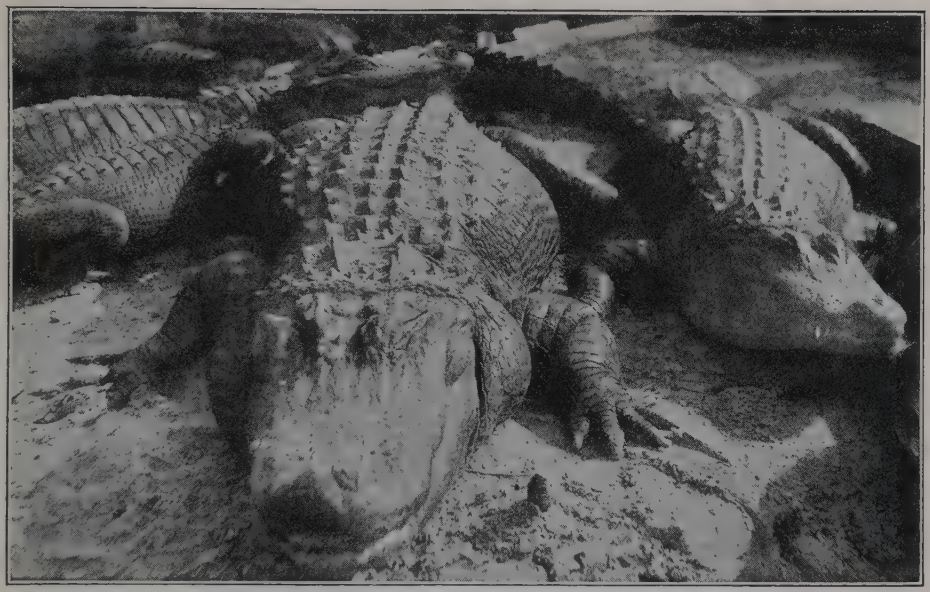
The common box turtle or tortoise carries its own fortress—a shell so nicely and evenly hinged at the bottom that it closes too tight to be torn open by the claws or fangs of any small animal. The box tortoise is a wanderer of the uplands and woodlands, eats almost everything from worms to strawberries, and often can be found about berry bushes.

Alligators and crocodiles

The alligator is a large reptile resembling the crocodile, from which it differs in having a shorter, flatter head, and feet less fully webbed. These creatures, which are shot for sport and for their hides, are in danger of being exterminated. Alligators grow slowly; when fifteen years of age they are barely two feet long. Nearly one hundred years are required for them to reach their full length of sixteen feet. They always eat, like some turtles, under water. They are timid, but defend themselves viciously. The young are hatched by the sun from eggs, of which the female lays 200 or more in great heaps, each egg being little larger than a hen's egg.

The crocodile is a large, flesh-eating water animal, regarded as the most highly developed reptile. Only one species lives in this country. The head is more narrow than that of the alligator, and the snout is pointed instead of rounded, the tail is more vertically flattened, and the teeth are longer and more pointed. As the crocodile is only about two-thirds as heavy as the alligator, it is more agile. The average length of a crocodile is about ten feet. It utters a short, loud bark or croak.

ALLIGATOR EGGS HATCHING IN THE SUN
Each egg is a little larger than a hen's egg. The female lays 200 or more in great heaps.



THE BIG ALLIGATOR FACES THE CAMERA

This large reptile differs from a crocodile in having a shorter, flatter head and feet less fully webbed. The alligator has a rounded snout, while the crocodile's is pointed.

The gavial, a fish-eating crocodile, does not inhabit this country but is often seen in our zoological gardens. It attains a length of twenty feet and may be distinguished from the crocodile by the length and slenderness of its snout. Its mouth and jaws are weak by comparison.

WHEN AND WHERE TO HUNT OUR REPTILE FRIENDS

Look for snakes and turtles when the pussy willow buds begin to drop, when the spring peeper is singing—for once the grass is high and thick, and the foliage too dense to see through, the snakes and many of the turtles are too well hidden for us to find. The best time to study these wild creatures is in the spring. This is the time when birds are building their nests. Then the box tortoise climbs out of its winter bed of dirt and leaves; then the spotted turtle bobs up from its long sleep deep in the mud, and then the black snake glides from the tiny entrance, that leads from its winter den underground.

Many people are misinformed about reptiles. We are likely to believe almost anything about things we do not understand. As a matter of fact, reptiles are not nearly as dangerous as is commonly supposed, and they are among the most interesting of all living creatures. A study of them not only will dispel the feeling of fear and repugnance, but also will disclose a new world of fascinating facts. Most reptiles are valuable because they eat harmful insects and rodents. They should not be killed, and you can help conserve them by learning about them and then educating others. Begin by learning to recognize the poisonous kinds.

A MONUMENT TO BIRDS

The Seagull Monument, Temple Square, Salt Lake City. This monument was erected in remembrance of the part played by gulls in devouring great swarms of locusts which threatened to destroy all the crops.

SWANS

THE STORY OF BIRDS

IF we had lived six million years ago, we might have seen strange, bird-like creatures gliding about in the air. We would have recognized them immediately as birds, because they had feathers, and we know that no other animals have possessed that kind of covering. If we had been able to creep up close to them, we would have noticed that they differed from crows, which they resembled to a certain degree, and from hens and sparrows and eagles and all the rest of the birds that we know, in three ways. In the first place, there was a row of good-sized teeth in each jaw. Secondly, there were three claws at the bend of each wing, which enabled the bird to crawl about in the same way as any animal with two arms and two legs. Thirdly, the tail was quite different from that of the birds that we know. Instead of spreading out in the shape of a fan, as the tail of a pigeon or a hawk does, it was long, like that of a lizard, and the feathers stood out on either side of the fleshy base, just as you see in the illustration.

Beneath the peculiar tree in which the bird sat and ate, scaly, four-legged, long-tailed animals crawled about on the ground, and some of them may have climbed up the trees. These animals were lizards, in appearance very much like the lizards that we see today in the warmer countries. And if we had thought very much about the two animals we would have said, "Why, these two creatures are greatly alike, only one is covered with feathers and glides about from tree to tree or from a tree down to the ground." And we

ARCHAEOPTERYX

No man has ever seen this ancient bird. Only a few skeletons have been found. The artist has shown us how *Archaeopteryx* probably looked.

CONCENTRATION OF WILD DUCKS

Above a forest-bordered lake in Arkansas, a retreat for wild fowl. Game sanctuaries of this sort are essential for our feathered friends.

would have been right in our guess, because our bird, with its teeth and long tail and claws, was descended from a lizard. Birds of today still carry a few traces of their ancestry; and if we look at the scales on the legs of a chicken or a turkey, we can see just a tiny bit of evidence of the lizard ancestry of the bird.

But as no man ever saw one of these ancient birds, we must be content with knowing them only by their skeletons. Even these are very rare, as only two are known, and they have been christened *Archaeopteryx*, the Greek word for "ancient winged animal."

All birds have come from *Archaeopteryx* and its cousins. They have spread themselves out all over the world, changing their shape and size as they grew, becoming brilliantly colored or somber hued. Wherever man has gone, even in the cold waste spaces of the Arctic and the Antarctic, he has always found birds ahead of him.

The vast numbers of birds

The bird is one of the most abundant creatures found upon the earth. About 20,000 different kinds of birds are known, and the United States has a very good share of them. They range in size from such diminutive forms as the calliope humming bird, a little fellow that lives in the western United States and never grows larger than three and one-half inches long, to the California condor, ten feet across the wings, or to the great white pelican, eight to nine feet across the wings. Of course these birds are small when compared with an ostrich, which often weighs two hundred and sometimes three hundred pounds. But the

ostrich does not fly, so he can afford to be much heavier.

How birds fly

Not all birds are able to fly rapidly, or for any great distance. Some fly swiftly for a short distance, and others, like the ostrich, the emu, the cassowary, and the rhea, or South American ostrich, are unable to fly at all. The shapes of wings differ, and we can tell, almost, by looking at a wing, what kind of a flier its owner is. The turkeys, chickens and quails have short, rounded wings, and we know that they never soar high in the air. They are able to fly swiftly from the ground up into a tree, or to rise rapidly, as the grouse and pheasants do, and then sail slowly back to earth again. The long, narrow-winged birds are the ones that fly with the greatest ease. The longest-winged birds are the albatrosses, found in the southern oceans. Their wings are often fourteen feet across and less than a foot wide, and their owners can sail for hours at a time with almost motionless wings, taking advantage of every gust of wind to force themselves a little higher in the air.

If we observe a frightened bobwhite or quail and an albatross, flying up from the ground, we will notice a vast difference. The bobwhite, with its short wings, flies up at a rapid rate and is off before we know it. But the albatross is quite different, and it must run laboriously along the ground, or flap along the surface of the water, often for hundreds of feet, before it can get enough impetus to rise above the earth.

When we think of birds moving their wings as fast as they do, we wonder how they can do it. The humming bird vibrates its wings so rapidly that we cannot see them, and homing pigeons have been known to travel 700 miles in one day, at almost a mile a minute. No other animal can move so steadily or so rapidly.

Compared with ourselves, or any other animal, the whole life of birds is lived at a very rapid rate. They breathe much faster than we do, and

TYPES OF BEAKS

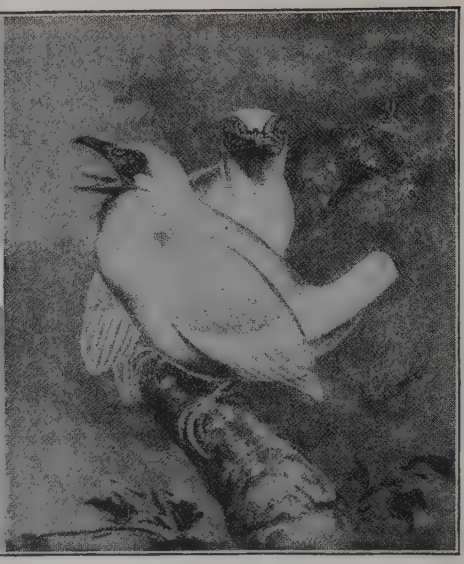
a, flamingo; *b*, spoonbill; *c*, yellow bunting; *d*, thrush; *e*, falcon; *f*, duck; *g*, pelican; *h*, avocet; *i*, black skimmer; *k*, pigeon; *l*, shoebill; *m*, stork; *n*, arocari; *o*, stork; *p*, bird of paradise; *q*, swift. (From Sedgwick.)

their pulse is speeded up to a remarkable degree. To hold a frightened bird in one's hand, and listen to the beating of its heart, is to question why it does not burst.

The speed of living is to a great extent dependent upon the way birds breathe. In other air-breathing animals with backbones, such as man, the other mammals, reptiles and frogs, the air is breathed into the lungs, where the necessary gas, oxygen, is extracted and sent with the blood to the rest of the body. This also happens in the bird. But in addition to passing into the lungs, the air goes to a series of sacs in the body. In many birds, the air actually enters the bones themselves, which, to serve this purpose, are hollow. Thus, a wounded swan, with its wind-pipe or trachea blocked up, has been known to breathe through the open end of a broken wing bone.

WAXWINGS
The waxwing has many of its brownish feathers tipped with red or yellow.

MANAKIN
Brilliantly colored, with a feather beard. The beating of its wings in flight sounds like the whirr of a spinning wheel. It lives in the forests of Central and South America.



BELL BIRDS
The bell bird has a note like the sound of a bell. When many are calling the sound of note following note is like the beating of hammers on anvils.

Probably the secret of the bird's ability to fly for hundreds of miles at high speed during migrations lies in bringing oxygen in direct contact with the tissue of the body in this manner.

How birds work for man

The value of birds to mankind is not always easily seen. Yet their place in the world is a very important one, and it is doubtful whether, if they were absent, man himself would not perish from the earth.

While man has used chickens, turkeys and geese, and their eggs, for food, the hosts of other birds have been helping him along by doing police duty. They have protected his crops from destruction by eating the insects, rats and mice that would destroy his grain. Besides this, dozens of kinds of birds feed upon weed seeds, which, if allowed to grow, would choke the crops that the farmer has planted.

One of the few monuments dedicated to birds was erected in Salt Lake City, Utah, in remembrance of the part played by gulls during the early days in that region. The ripening crops were threatened by great swarms of locusts. But just as the settlers had lost hope, thousands of gulls appeared and quickly devoured the insects.

Other facts relating to birds as pest destroyers are of great interest. The calculations that have been made of the weed and vermin destroying capacities of various birds are quite astounding. Professor Beal estimates that the tree sparrows destroy 875 tons of weed seed yearly, in the state of Iowa alone, and he also states that a single mourning dove has eaten the surprising number of 7,500 seeds of the yellow wood sorrel in one day.

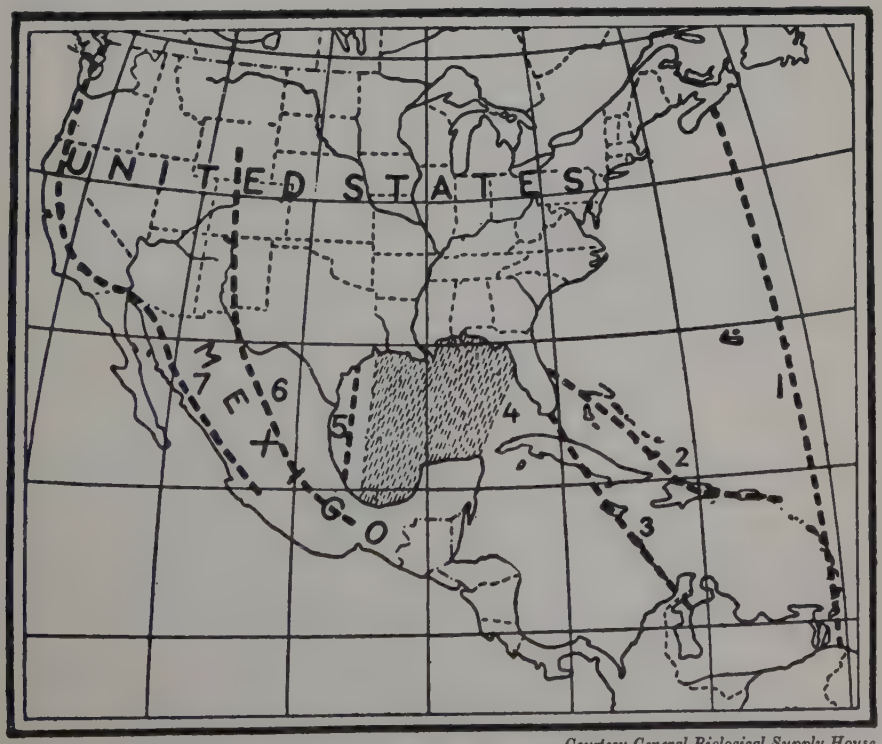
Endless examples of the value of feathered animals to man might be quoted. In 1885, the State of Pennsylvania offered a bounty of fifty cents for every hawk and owl brought in dead. After two years, when 180,000

birds had been destroyed, the increase of rats and mice was so alarming that the bounty law was repealed. It was estimated the damage done to crops by these rodents amounted to $2,000,000.

When the robins arrive each spring, and the wild geese honk as they fly northward, hosts of human beings see and hear them, and are thrilled by this contact with wild creatures. From the earliest days, man has been interested in birds. They represent a source of food supply, and he has always been charmed by their songs and colors. The people of many primitive races decorate themselves with feathers, and often certain kinds can be worn only by the greatest of warriors. Our Indians wore beautiful feather headdresses, made, for the most part, of eagle feathers, and the warriors of some African tribes were allowed to wear an ostrich plume only when they had killed an enemy.

THE BIRD THAT CATCHES FISH FOR ITS MASTER

In every possible way, birds have been employed by man. He has used their feathers to make coverings for himself and for decorating his dress. He has used their flesh for food; and, not content with that, he has made them catch food for him. In China and Japan, the sea birds known as cormorants are trained for use as fish traps. A man with a number of these birds goes to the fishing grounds. He throws a bird overboard, and it immediately dives, catching as many fish as it possibly can. But the wily fisherman prevents the bird from completely



Courtesy General Biological Supply House

BIRD MIGRATION ROUTES

This map shows the principal routes used by birds in their migrations between North and South America.

swallowing the fish by means of a small metal ring, which fits rather tightly over the lower part of the bird's neck. Thus the bird must hold in its throat all of the fish that it has caught. When the cormorant has caught a fish, its master hauls it into the boat by means

BALD EAGLE

Head feathers of purest white give this majestic bird its name. As you know, the bald eagle is the emblem of our country. Photograph by E. R. Sanborn, New York Zoölogical Society.

of a small rope that is attached to one of the bird's legs, and forces it to disgorge its capture. Then, so that the bird may not become discouraged, two or three of the smaller fish are given to it.

SOME FLESH-EATING BIRDS—EAGLES, HAWKS AND OWLS

There are eaters of flesh among the birds, just as fierce, if not so powerful, as the lions and tigers among the mammals. The eagles, hawks and owls pursue and kill their prey as relentlessly as any great cat. While a few destroy birds that are of great value to us, many are enemies of the rats and mice so destructive to the crops of farmers.

THE TWO AMERICAN EAGLES

In America there are only two kinds of eagles, the bald and the golden. The bald eagle, as everyone knows, is the emblem of our country. He is not really bald, of course, but the feathers of his head are of the purest white, which gives rise to the name. In the adult, the tail, also, is white, but until the bird is three years old, it is entirely dark brown in color. The bald eagle is found throughout America, but most frequently along the coasts or near the great inland lakes and rivers. It feeds largely on fish but is swift enough on the wing to catch such strong fliers as wild ducks, when it wishes to do so.

The golden eagle is found in mountainous regions throughout the northern hemisphere. In eastern North America, it is less common than the bald eagle, but in the great mountains of the west, it is fairly abundant. The golden eagle is a swift and powerful bird, feeding entirely on small animals and birds. One often reads stories of children being carried off by golden eagles, but there is no truth in these stories, for no bird of this species can carry a weight of more than a few pounds. Golden eagles and young bald eagles are similar in color, but can always be distinguished by the fact that the legs of the golden are feathered to the toes, while those of the bald are bare.

HAWKS, GOOD AND BAD

There are numerous species of hawks in America, ranging from the large "chicken-hawk," familiar to all of us as a soaring speck in the summer sky,

to the diminutive sparrow-hawk. The red-tailed and red-shouldered hawks, commonly known as "chicken-hawks," are really beneficial species, as they feed almost entirely on rats and mice. Most of the chicken stealing so often laid to these practically harmless birds is done by the fierce and sly Cooper's and sharp-shinned hawks, which are very destructive to bird life of all sorts.

Owls and their habits

The majority of owls are usually purely nocturnal—night birds. One or two species usually can see quite well in a bright light, but the majority cannot. Their eyes are so formed that they can collect light from what to us is darkness. They can see when the daylight is not quite gone; but in the direct light of the sun they are dazed.

The owl works and feeds when we are asleep. It has eyes differently placed from those of any other bird—close together in front, so that it must look straight ahead. To make up for this, it can turn its head with the greatest ease in any direction. The power of its eyes in the darkness is remarkable. Most of us, if we were quite close to a field mouse or rat moving stealthily over a field, would do well to see it against the earth, like which its coat is colored. But the owl sees it from afar through the darkness, pounces noiselessly down, and seizes it. The owl can catch the mouse and the mole and the rat; it can catch fish as they rise to the surface of the water.

There are about 200 species of owls. Some are tiny; some are big eagle owls, twenty-eight inches in length, very fierce and strong, ready to attack a man who goes near, able to kill young deer and large game birds, and to do battle with the golden eagle. The courage of one of these owls goes in the daytime. Then little birds, led by a crow, may find the owl, entice it out into the open, and lead it a terrible life.

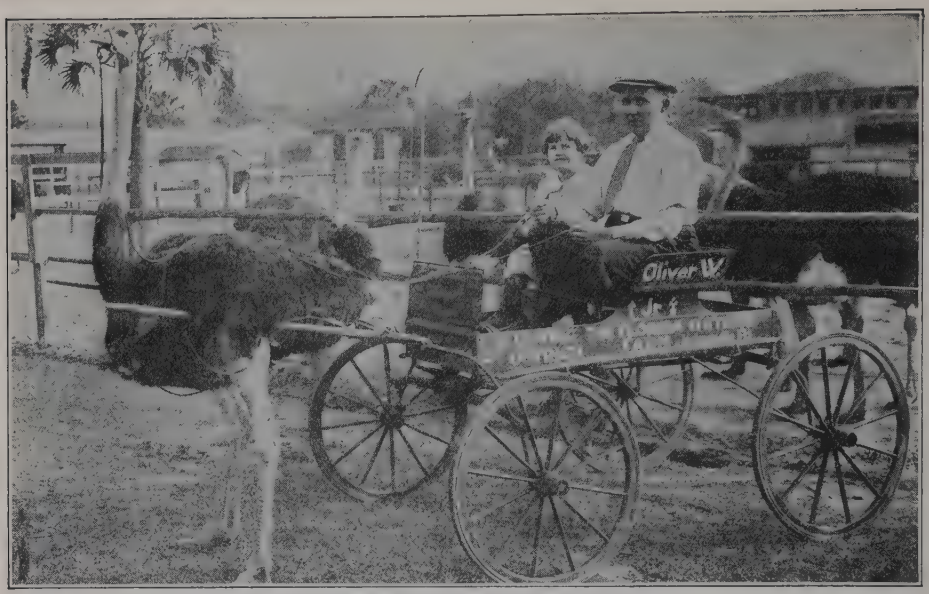
The hawk owl is one of the few which work by day. It is big and strong and savage. There are owls with great ear-tufts of feathers, and owls with none at all; some are snowy

Courtesy Eastman Kodak Co.
ROUGH-LEGGED HAWK

white, others are mottled. Some live in the deserted burrows of ground squirrels or prairie dogs; some make burrows for themselves. Mostly they live in hollow trees, or in church belfries or other high towers. Among so many owls, of course, there are those which do harm, but the most of them do more good than evil.

The ostrich and its relatives

As we have already seen, the ostrich is the largest bird living today. Although its ancestors undoubtedly possessed the ability to fly, the wings of the modern bird are so weak that they cannot support its great bulk. However, the strength of the legs has been developed to cover this lack, and the ostrich can run fast enough to escape the swiftest enemy.



A STRONG SWIFT STEED

The ostrich farm is always an interesting place to tourists. This picture gives a good measure of the size of this largest of living birds.

If the wings are useless for flying, at least they have made the ostrich famous for the beautiful plumes they bear. They have long been sought as ornaments and the demand finally became so great that the ostrich was domesticated. Until recent years ostrich farming was one of the great industries of South Africa. Many of these birds were imported to America, and ostrich farms were established in Florida, Arizona and California. For some time, these farms flourished, but a sudden whim of fashion banished the lovely plumes as millinery ornaments. The ostriches were no longer able to pay for the food they ate, and were sold for what they would bring, or destroyed because there was no longer a market for them. Today, ostrich farms are maintained in America simply as show places, and the plumes are sold merely as souvenirs.

The true ostrich is an African bird; but various ostrich-like birds are found in other parts of the world. The rhea, which is about half the size of the ostrich, is found on the great open plains, or pampas, of southern South America. Here it roams with herds of guanacos, the wild ancestors of the llama, and is hunted for its flesh and for the wing plumes.

Still another bird of this group is the emu, a native of Australia. Its cousins, the cassowaries, are found there, too, as well as in New Guinea and some of the neighboring islands. The emus and cassowaries are especially interesting, because of their curious breeding habits. The females are really the "suffragettes" among birds, for once they have laid their eggs, they take no further interest in them, and the work of incubation and rearing the young is left entirely to the fathers.

Turkeys and other fowl-like birds

When the Pilgrims came to America, they shot many wild turkeys for food. For many years after, the bird was hunted, until now it is rare in the wild

COLONY OF FLAMINGOS IN THE BAHAMAS

Photograph from a mounted group in the American Museum of Natural History, New York City. The flamingos are near relatives of ducks and geese. In the European species the plumage is of a rosy tint, deepening into scarlet crimson on the wings. In the American bird this tint becomes scarlet over the entire body.

state, and is fast disappearing from all parts of the country that man has invaded. Our domestic turkey is not the same as the wild one, but is descended from birds that were taken from southern Mexico to Europe in 1530 and later brought back to this country. Only one other wild species

Courtesy Gen. Biol. Supply House

PASSENGER PIGEONS

These beautiful birds have vanished from the earth. The familiar mourning dove closely resembles the passenger pigeon.

is known and that is a beautiful bird called the ocellated turkey. It comes from Yucatan and is noted for the brilliant blue and gold of its plumage.

The turkeys belong to the great group of fowl-like birds, which includes our domestic poultry, the beautifully-colored pheasants, the peacock and the many kinds of grouse and quails. America is especially well endowed with birds of the last two groups. Unfortunately, the bobwhite and ruffed grouse in the East, and the sage grouse, prairie chicken and some others in the West, are rapidly becoming reduced by constant shooting.

The Pigeon That Carries Messages Hundreds of Miles

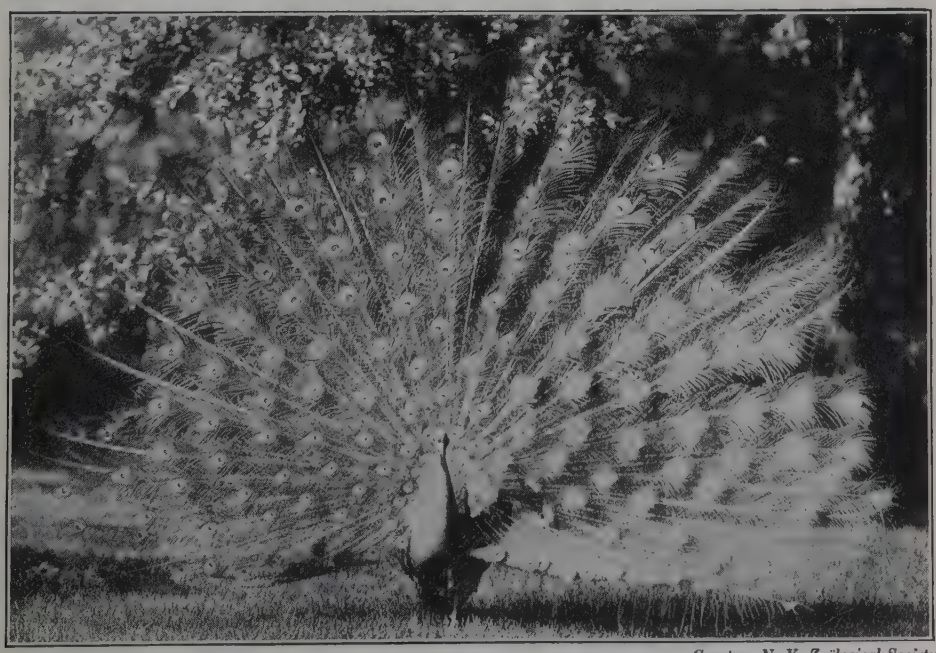
Since very early times, homing pigeons have carried messages, their flight being always directed to their home loft. During the great war, thousands were employed in carrying dispatches from the front-line trenches to the officers stationed in the rear, through places where a human messenger would have been killed. So efficient have pigeons become in returning to their homes that they will come back hundreds of miles at high speed. Actual records have been made, showing that a single pigeon has flown 100 miles at the rate of almost a mile and a half a minute; and four birds have flown 700 miles in one day, at about seven-eighths of a mile a minute. Such speed is unknown among any other group of animals, and is equalled only by the machines that man has made.

How More Than Two Billion Birds Vanished From the Earth

A hundred years ago, a beautiful bird, called the passenger pigeon, was so abundant in the United States that when the birds flew overhead they often darkened the sky. Nowhere else in the world have such large numbers been known. A single nesting area, where untold thousands roosted and each pair incubated its single egg, occupied a space twenty-eight miles long by three miles wide. So many birds congregated on the trees that it was unsafe for men to pass below, as the birds' weight was so great that branches constantly broke off. Wilson, one of the first American naturalists, estimated that a single flock which he had observed contained about 2,230, 272,000 birds. But the sad lesson to learn is, that even these vast numbers of birds were not enough to withstand the attacks of man. Whenever these pigeons gathered, men came and

GREAT FLYING CAGE

The commodious home of the water birds at the New York Zoölogical Park.



PEACOCK *Courtesy N. Y. Zoölogical Society*

With long gorgeously colored train elevated to form a beautiful spreading fan. The peacock moves slowly and in a dignified manner.

killed them by the thousands, and now the passenger pigeon has vanished from the earth.

Another bird, the mourning dove, so named because of the sadness of its call, is found over almost all of the United States. It closely resembles the passenger pigeon, and is often mistaken for it. However, it is easily

YOUNG HOATZIN

Showing admirably the claws on the wing. Photographed by Mr. Beebe.

known by its much smaller size and by the color of its plumage, which is brown rather than bluish, as in the passenger pigeon.

More than 600 different kinds of pigeons are found scattered throughout the world. They range in size from the tiny ground dove of our southern states, no larger than a sparrow, to the great crowned pigeons of New Guinea. These birds are as large as turkeys, and wear on their heads a beautiful tuft of ornamental plumes. These feathers, known as "gouras," have been greatly sought by milliners, and immense numbers of crowned pigeons are slaughtered for this reason alone.

THE HOATZIN—A LIVING RELIC OF ANCIENT DAYS

Living in low trees along the banks of sluggish rivers in tropical South America, is found a curious bird known as the hoatzin. He is really a left-over from very early times, for he still retains many of the characteristies of his reptilian ancestors. When the baby hoatzin first sees the light of day in the clumsy stick nest in which he is hatched, his featherless wings are armed with two sharp claws, exactly like those of a lizard. If the chick is alarmed or disturbed, the purpose of these claws becomes evident, for he uses them freely to assist himself in climbing out of the nest and even among the branches of his home tree.

HOATZINS IN CAPTIVITY

The first two to be kept in a cage. Brought from British Guiana and photographed by Mr. Tee-Van.

Once he has become fledged, and has gained the use of his rather feeble wings, the claws become useless, being completely buried in the plumage.

AN ELEGANT BIRD GENTLEMAN

Far down in the south, in the frigid Antarctic Ocean, live the penguins. They are the "seals" among birds, for they seek their food in the sea. Their wings, which are short and stiff, like the flippers of a seal, are useless for flying, but make excellent pro-

EUROPEAN STORK *Courtesy N. Y. Zoölogical Society*

Long the subject of fable and story, the stork has always been given friendly protection. But for some unknown reason the European stork is slowly disappearing.

pellers when the bird is in the water. The largest of all the penguins is the great emperor, which stands nearly four feet high, and is an elegant gentleman, in his dark coat, white waistcoat and orange tie. The emperor lives on the great ice floes, where there is no material for building nests. But this is no great problem, for the bird holds its single egg on its feet, warming it with a soft fold of downy skin, which completely covers the treasure.

How the Gull Opens Clams

When Christopher Columbus sailed across the ocean, he and his disgruntled crew were happy when they saw a bird fly near their vessel. It showed that land was near. Even now we are glad to see the gulls that come to meet our vessel when it is a day or so offshore, and to watch them following our ship, picking up whatever scraps of food are thrown overboard. Most of our gulls live near the shore, especially about bays and harbors, although they are found on fresh-water lakes also. They are scavengers to a large extent, and will eat almost anything that they can find. Many of them have learned an interesting way of opening clams. A gull's beak is not strong enough to smash the strong shells of a clam or a snail. So the gull takes the clam in its bill, flies up into the air, drops the clam upon rocks, where it is broken, and then swoops down to devour the contents.

But the gull is not always successful in keeping his food. A close relative of his, called the skua, a large, brownish bird, takes advantage of him by stealing his food. When this bird sees that a gull has captured an interesting morsel, it chases and frightens the original owner by such a fierce display, that the food is disgorged, or given up, and the skua then devours it himself.

The Stork That Builds Its Nest on a Cart Wheel

One of the most interesting examples of friendly relations between birds and men is that of the white stork of Europe. For more years than one could count, the stork has been the subject of fable and story—every child who longs for a baby brother or sister knows that he must keep in the good graces of the great white bird. So strong is the attachment of the people

of Holland and the lower portions of Germany for the stork, that farmers place disused cart wheels on the roofs of their houses or on the tops of tall poles to hold the huge stick nests of the birds. For some reason, not well understood, the stork is slowly disappearing, in spite of the efforts of its friends to give it protection.

Three kinds of storks are found in the Western Hemisphere. Only one resembles the stork of Europe, and that is the maguari stork of South America. In the same countries lives the huge jabiru, which has a coal-black head, almost bare of feathers, and a bright red neck. The head is not quite bare, because at the back of its otherwise bald black crown, it wears a tuft of pure white down, curiously like the wisp on the head of an aged negro. In the southern United States lives the wood ibis, which is really a stork, and the only one found in our country.

Courtesy N. Y. Zoöl. Soc.

SECRETARY BIRD

This bird from Africa is here seen killing a snake.

THE GREAT ARMY OF WATERFOWLS

Of the great army of waterfowls, including the swans, geese and ducks, many kinds are found in America. The swans, of course, are the largest of all. With their snowy plumage and gracefully curved necks, they are surpassed in beauty by few birds. Two kinds of swans are found in the United States. The larger of these, the trumpeter, is now so nearly extinct that, outside of zoölogical gardens, only one small colony is known to exist. This little group is struggling for existence, under the protection of the Canadian government. The second American species, the whistling swan, is known by its smaller size and by a yellow spot on the bill. The whistler is still fairly abundant; and during the winter months great numbers may be seen on favorite feeding grounds along our southern shores.

The commonest of the wild geese of North America is the Canadian. This bird breeds in the northern portions of our continent, often close to the Arctic Circle. In midsummer, when the goslings are only partly grown, the old birds commence their molt, and then they show a curious weakness that is common to all waterfowl. The long feathers of the wing, which are known as the primaries, are shed together, so that the bird is quite unable to fly. The Indians take advantage of the helpless condition of the geese, and great flocks, both old and young, are driven into nets and slaughtered. However, in spite of these heavy losses, the Canadian goose continues to hold its own, and one of the first tokens of spring is still the honking of the flocks as they fly northward.

There are many kinds of wild ducks in America, but they are rapidly becoming reduced in number. Two main causes are responsible for this—increasing cultivation of the land, including drainage of swamps, and overshooting by sportsmen. Certainly the great "rafts" of wild ducks, often numbering thousands of birds, have become a thing of the past.

LAUGHING JACKASS
This bird is really a kingfisher. It delights to mimic the human voice in laughter.

KAKA PARROT
Though harmless itself, this bird is related to the destructive kea which kills sheep.

LYRE BIRD
This beautiful Australian bird has the strangest tail known among birds.

THE SECRETARY BIRD AND THE SNAKE

The secretary bird, which lives in South Africa, eats anything that it can kill and swallow, but it takes great delight in killing and devouring snakes. When the bird finds one, it walks with its wings outspread, intently watching every movement of the snake. If the reptile leaps toward him, the blow is warded off by the wing, or the bird jumps high into the air. Finally the bird runs rapidly toward the snake, and kills it by stamping it with its feet. The power delivered by the kick of this bird is great, and the snake is quickly destroyed and swallowed, head first. So valuable are these creatures in the places where they live, that no one is allowed to harm them.

A NEW ZEALAND PARROT THAT HAS BECOME A PEST

There are hundreds of different kinds of parrots in the world, but only one is native to the United States, and even that one may be extinct. Years ago this bird, called the Carolina parrakeet, inhabited most of the country east of Texas and as far north as the Great Lakes. But now it has almost disappeared. The last ones were observed in Florida in 1906, although one that was in captivity in the Cincinnati Zoölogical Gardens lived until 1914.

Parrots usually lay two white eggs in holes in trees. They feed upon seeds and fruit. But in New Zealand, since the time the country was settled by white men, the kea parrot has changed its habits. Now it often eats meat and is particularly fond of some of the internal organs of sheep. The bird alights on the back of the sheep, digs its way through the wool and skin, and removes the kidneys through the hole it has made. As the sheep usually dies after the attack, this parrot has become a pest, and is killed whenever possible.

Parrots, especially the African gray parrots and the large green Amazon

GRAY PARROT

This bird from West Africa is a wonderful mimic. It can imitate birds and beasts, whistle a song and imitate the sound of machinery.

LOVE BIRDS

These small parrots thrive as cage birds though their home is in Africa. If one dies its mate sometimes pines away.

parrots, readily learn to talk and to imitate other sounds. The cockatoos and most of the smaller parrakeets, however, are less clever and often do nothing but shriek. One green parrot at the New York Zoölogical Park was taught its own scientific name and repeated "*Amazona amazonica amazonica*" on every possible occasion. Unfortunately its cage mates, not of the same kind and possessing quite different names, also learned the same words.

THE STRANGE NESTING HABIT OF THE HORNBILL

Birds have many curious nesting habits and the hornbills have perhaps the strangest of all. These birds live in tropical portions of the Old World, and are remarkable for the great size of their bills. At nesting time, the female selects a convenient hole, high up in a tall tree, and here she lays her single egg. As soon as this has been done, her mate promptly seals the entrance with mud, closing her within. However, he leaves a narrow slit, and through this he faithfully feeds the brooding bird, continuing until the youngster is large enough to take wing. What the fate of the prisoners might be if an accident should overtake the father is easily imagined.

In South America is found a group of birds somewhat resembling the hornbills, but really not closely related to them. These are the toucans. Their bills are almost as large as those of the hornbills, and gaudily colored with all the hues of the rainbow. Toucans sleep in hollow trees, and have a curious way of folding their heads and tails over their backs, so that they are able to occupy a space that would seem very much too small to hold them.

HUMMING BIRDS—THE FEATHERED FAIRIES

Strange as it may seem, emeralds and rubies and garnets, as well as fairies and wood sprites, exist as living creatures. So brilliant and so graceful in flight are the humming birds that the men who named them have given them such names as "Golden-crowned Emerald," "Green - headed Wood Nymph" and "Crimson - throated Wood Star." Their brilliant colors, greens and blues and reds and purples and yellows, are often metallic, and shine out like precious stones.

All of the humming birds are small, ranging from the smallest known bird

HORNBILL

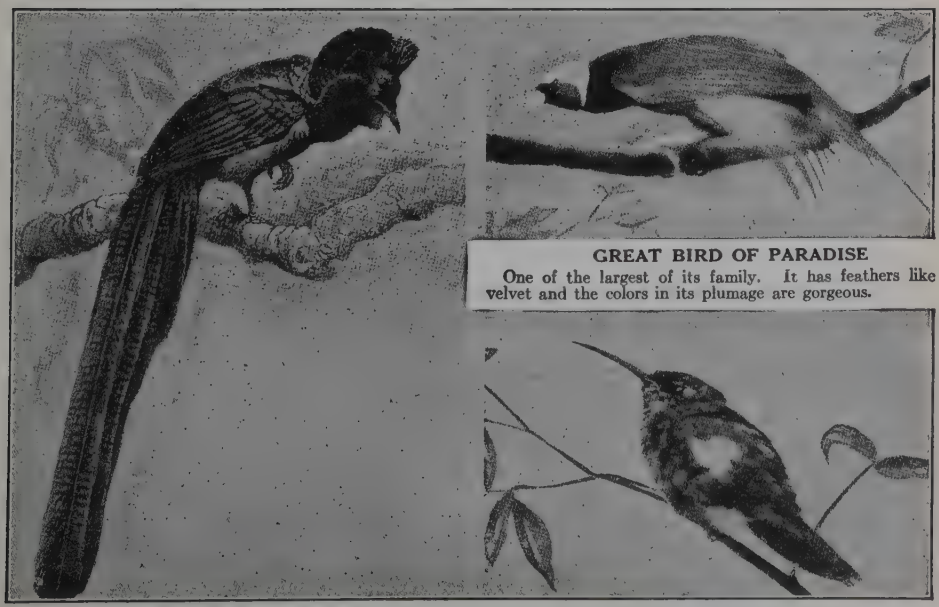
Hornbills live in Africa and in India. Kafirs in time of drought kill a hornbill as an offering for rain.

TOUCAN

The toucan's enormous bill is honeycombed with air cells to reduce the weight.

to the topaz humming bird, seven inches in length. They feed upon tiny insects and honey that they sip from flowers. They usually lay two white eggs in a nest made of plant down and lichens, that is attached to the upper side of a twig.

In the eastern United States only a single species, the ruby-throat, is found. In the South, however, there are a number of different kinds. Our ruby-throat is a plain little bird compared to some of the South American forms. Besides their brilliant colors, many of them have long plumes and crests of peculiarly-shaped feathers. Some have ruffs that surround their heads, or long plumes that arise from their tails. Others, called the puff-legs, have circular bands of white feathers on their legs, which are flashed out at intervals during mating season.



GREAT BIRD OF PARADISE

One of the largest of its family. It has feathers like velvet and the colors in its plumage are gorgeous.

GORGET BIRD OF PARADISE

Lovely beyond description with feathers of black, purple, copper, green and gold.

HUMMING BIRD

A brilliant little bird with whirring wings. It flies so rapidly that its wings hum like those of a bee.

TWELVE-WIRED BIRD OF PARADISE

This bird has plumes similar to the great bird of paradise, but six on each side have the shafts bare like wires.

WEAVER BIRD

Hundreds of sociable weaver birds build nests together under one neat thatched roof made in a tree.

The rapidity with which the wings of these birds move is remarkable. When they hover in front of a flower, sipping honey, the wings move so swiftly that only a blur can be seen on each side of the bird's body.

In Africa the humming bird's place is taken by birds that resemble them in size, shape and color, but belong to an entirely different group, called the sunbirds. When feeding, they do not hover in the air as the humming birds do, but perch upon a twig before the flowers from which they obtain their food.

THE BIRD THAT BAWLS LIKE A CALF

In South America dwells a family of birds known as cotingas or chatterers. Some of the members of this group are remarkable for their brilliant coloration or strange ornaments, while others are almost repulsively ugly. The plumage of one, known as the cock of the rock, is an intense fiery orange, set off with black, while another is bright, shining blue above, with breast of deepest purple. The umbrella bird is somberly colored; but from the back of its head grows a huge, spreading crest, which overhangs

SATIN BOWER BIRD

This member of the crow family is a great gardener and builder and likes to build a bower with flowers and gay feathers.

JAVA SPARROWS

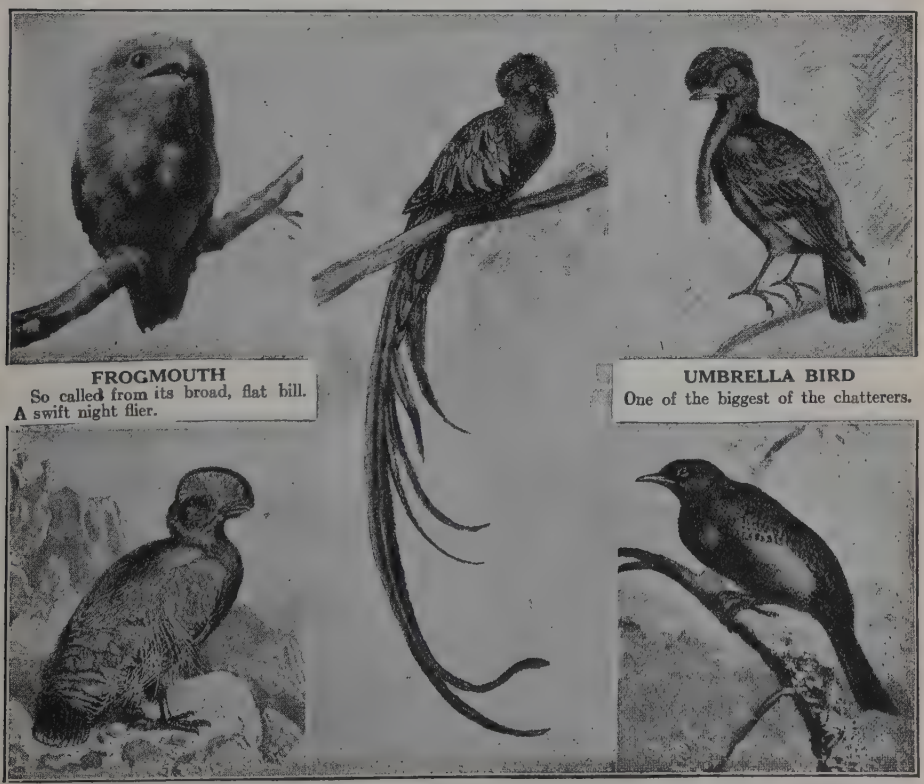
This type of the weaver bird is common in captivity. The Java sparrows have smart white feather collars.

the crown, very much like a sunshade. The resemblance is increased by a long, feathered wattle, which hangs below the throat, like a handle. The ugly duckling of the family is the calf bird, a creature as large as a crow, and clothed in brown. Its head is bare of feathers and decidedly unpleasant in appearance. It lives up to its name by emitting a hoarse, calf-like bawl, which can be heard at great distances through the jungle.

Birds of Paradise

When the first skins of the birds of paradise were brought to Europe, they were without feet. The men who first saw them thought that the birds had never had feet and could not alight on the ground or upon trees. Interesting stories grew up about these footless birds, one of them being that the females nested and laid their eggs and reared their young while sitting on the back of the male bird as he flew about.

But scientists later discovered that the feet had been cut off when the birds were skinned, and that the birds had feet and legs just the same as any other bird. Even in the present day, however, we have a reminder of this legend in the scientific name of the greater bird of paradise, which is known as *Paradisea apoda*, the last word of which means "footless." The birds of paradise come from New Guinea and many other islands in that vicinity.



FROGMOUTH
So called from its broad, flat bill. A swift night flier.

UMBRELLA BIRD
One of the biggest of the chatterers.

COCK OF THE ROCK
Brilliant orange red and crested to the tip of the beak.

QUETZAL
So named from its long green feathers.

BANDED COTINGA
A Brazilian bird which lives among the tree tops.

Although these birds are related to the somber-hued crows they rival the humming birds in gaudy colors and beautiful plumes. Some of them, like the greater and lesser birds of paradise, have long plumes that can be thrown up in a semicircle about the bird's head when it displays. The king bird of paradise is no larger than a thrush, but wears a coat of flaming scarlet, decorated with shields of brilliant green, at each side of the breast.

The satin bower bird is a close relative to the bird of paradise, and lives in parts of Australia. The bower bird is remarkable because it is one of the few birds that build playgrounds wholly separate from their nests and about which the birds spend most of their time. The bower is formed of small sticks, the lower ends of which are pushed into the ground, and placed in two rows, with their upper ends meeting so as to form a tunnel or bower. The bird takes great delight in decorating the bower and the ground surrounding it with shells and feathers. It shows an especial liking for blue objects.

The sparrow family

One of the most useful groups of native birds is the sparrow family.

The English sparrow is not a native, but was imported from Europe in 1851. It was hoped that this immigrant would destroy various tree caterpillars, and, in fact, especially at nesting time, it has eaten large quantities of smooth caterpillars. But the English sparrow is regarded generally as an undesirable. It is noisy, dirty and harmful to grain, fruit and vegetables. It also drives away desirable, insect-eating birds.

While some of the tribe wear gay suits of many hues, most of the sparrows are clad in modest brown tints, and as they spend much of the time in grass and weeds are commonly overlooked. The sparrows (with the exception of the English sparrow) lay the farmer under a heavy debt of gratitude by their food habits, since their chosen fare consists largely of the seeds of weeds. Selecting a typical member of the group, the tree sparrow, for instance, one-fourth ounce of weed seed per day is a conservative estimate of the food of an adult. On this basis, in a large agricultural state like Iowa, tree sparrows annually eat approximately 875 tons of weed seeds. Only the farmer, upon whose shoulders falls the heavy burden of freeing his land of noxious weeds, can realize what this vast consumption of weed seeds means in the saving and cost of labor.

Some idea of the money value of this group of birds to the country may be gained from the statement that the total value of farm products in the United States in 1920 was more than $10,000,000,000. If we estimate that the total consumption of weed seed by the combined members of the sparrow family resulted in a saving of only one per cent of the crops—not a violent assumption—the sum saved to farmers by these birds in 1920 was more than $100,000,000.

Courtesy Eastman Kodak Company

PURPLE GRACKLE OR CROW BLACKBIRD

FAMILIAR AMERICAN BIRDS

THE following descriptions are of some of the birds which frequent our farms, orchards and suburban districts; some will be found even in the crowded city. To help in identification two pages of illustrations in color are inserted. These are by the distinguished bird artist, the late Louis Agassiz Fuertes.

Barn owl

The barn owl is one of the most beneficial of the birds of prey, since it feeds on small mammals that injure farm produce, nursery and orchard stock. It hunts in the open and secures such mammals as pocket gophers, field mice, common rats, house mice, harvest mice, kangaroo rats and cotton rats. It occasionally captures a few birds and insects. At least a half bushel of the remains of pocket gophers have been found in the nest of a pair of these birds. Remembering that a gopher has been known in a short time to girdle seven apricot trees worth $100 it is hard to overestimate the value of the service of a pair of barn owls.

Barn swallow

This is one of the most familiar birds of the farm and one of the greatest insect destroyers. From daylight to dark on tireless wings it seeks its prey, and the insects destroyed are countless. Its favorite nesting site is a barn rafter, upon which it sticks its mud basket. Most modern barns are so tightly constructed that swallows cannot gain entrance, and in New England, and some other parts of the country, barn swallows are much less numerous than formerly. Farmers can easily provide for the entrance and exit of the birds and so add materially to their numbers.

Insects taken on the wing make up most of the diet of the barn swallow; more than one-third of its food consists of flies. Beetles stand next in order and consist of a few weevils and many of the small dung beetles of the May beetle family that swarm over the pastures in the late afternoon. Ants amount to more than one-fifth of the whole food, while wasps and bees are well represented.

Bluebird

Familiar tenant of farm and dooryard, the bluebird is everywhere hailed as the harbinger of spring. Wherever it chooses to reside it is sure of a warm welcome. This bird, like the robin, phoebe, house wren, and some swallows, is very domestic in its habits. Its favorite nesting sites are crannies in the farm buildings or boxes made for its use or natural cavities in old apple trees.

Courtesy Eastman Kodak Co.

BOBOLINK

A bird long enshrined in song and story.

For rent the bird pays amply by destroying insects, and it takes no toll from the farm crop. The bluebird's diet consists of sixty-eight per cent of insects to thirty-two per cent of vegetable matter. The largest items of insect food are grasshoppers first and beetles next, while caterpillars stand third. All of these are harmful except a few of the beetles. The vegetable food consists chiefly of fruit pulp, only a small part of which is of cultivated varieties. Among wild fruits elderberries are the favorite. From the above it will be seen that the bluebird does no essential harm, but on the contrary eats many harmful and annoying insects.

Blue jay

The blue jay is of two natures—cautious and silent in the vicinity of its nest; away from it bold and noisy. Sly in the doing of mischief, it is ever ready to scream "thief" at the slightest disturbance. As usual in such cases, its remarks apply to none more than itself, a fact neighboring nest holders know to their sorrow, for during the breeding season the jay lays heavy toll upon the eggs and young of other birds, and in doing so deprives us of the services of birds more beneficial than itself.

About three-fourths of the annual food of the blue jay is vegetable matter, the greater part of which is composed of nuts, as acorns, chestnuts, beechnuts and the like. Corn is the principal cultivated crop upon which this bird feeds, but most of the corn taken is waste grain. Such harmful insects as wood-boring beetles, grasshoppers, eggs of various caterpillars and scale insects constitute about one-fifth of its food.

Bobolink

When American writers awoke to the beauty and attractiveness of our native birds, among the first to be enshrined in song and story was the bobolink. Few species show such striking contrasts in color of the sexes.

and few have songs more unique and whimsical.

In its northern home the bird is loved for its beauty and its rich melody; in the South it earns deserved hatred by its destructiveness. Bobolinks reach the southeastern coast of the United States the latter half of April just as rice is sprouting and at once begin to pull up and devour the sprouting kernels. Soon they move on to their northern breeding grounds, where they feed upon insects, weed seeds, and a little grain. When the young are well on the wing, they gather in flocks with the parent birds and gradually move southward, being then generally known as reed birds. They reach the rice fields of the Carolinas about August 20, when the rice is in the milk. Then until the birds depart for South America planters and birds fight for the crop, and in spite of constant watchfulness and innumerable devices for scaring the birds a loss of ten per cent of the rice is the usual result.

Bobwhite

The bobwhite is loved by every dweller in the country and is better known to more hunters in the United States than any other game bird. It is no less appreciated on the table than in the field, and in many states has unquestionably been hunted too closely. Fortunately it seems to be practicable to rear the bird in captivity, and much is to be hoped for in this direction.

Half the food of this quail consists of reed seeds, almost a fourth of grain, and about a tenth of wild fruits. Although thus eating grain, the bird gets most of it from stubble. Fifteen per cent of the bobwhite's food is composed of insects, including several of the most serious pests of agriculture. It feeds freely upon Colorado potato beetles and chinch bugs; it devours also cucumber beetles, wireworms, billbugs, clover-leaf weevils, cotton-boll weevils, army worms, bollworms and Rocky Mountain locusts. Take it all in all, bobwhite is very useful to the farmer, and while it may not be necessary to remove it from the list of game birds every farmer should see that his own farm is not robbed by eager sportsmen.

Brewer's blackbird

This bird is very numerous in the West and in autumn gathers in immense flocks, especially about barnyards and corrals. During the cherry season in California, Brewer's blackbird is much in the orchards. In one case they were seen to eat freely of cherries, but when a neighboring fruit raiser began to plow his orchard almost every blackbird in the vicinity was upon the newly-opened ground and close to the plowman's heels in its eagerness to get the insects exposed by the plow.

Caterpillars and pupae form the largest item of animal food. Many of these are cutworms. Beetles constitute over eleven per cent of the food. The vegetable food is practically contained in three items—grain, fruit and weed seeds. The grain is probably mostly wild, volunteer or waste, so that the bird does most damage by eating fruit.

Catbird

In many localities the catbird is one of the commonest birds. Tangled growths are its favorite nesting places and retreats, but berry patches and ornamental shrubbery are not disdained. Hence the bird is a familiar dooryard visitor. The bird has a fine song, unfortunately marred by occasional catcalls.

With habits similar to those of the mocking-bird and a song almost as

varied, the catbird has never secured a similar place in popular favor. Half of its food consists of fruit, and the cultivated crops most often injured are cherries, strawberries, raspberries and blackberries. Beetles, ants, crickets and grasshoppers are the most important items of its animal food. The bird is known to attack a few pests, as cutworms, leaf beetles, cloverroot and curculio, but the good it does in this way probably does not pay for the fruit it steals. The extent to which it should be protected may perhaps be left to the individual farmer. It should be lawful to destroy catbirds that are doing manifest damage to crops.

Chickadee

Because of its delightful notes, its confiding ways, and its fearlessness, the chickadee is one of our best known birds. It responds to encouragement, and by hanging within its reach a constant supply of suet the chickadee can be made a regular visitor to the garden and orchard.

The chickadee's food is made up of insects and vegetable matter in the proportion of seven of the former to three of the latter. Moths and caterpillars are favorites and form about one-third of the whole. Beetles, ants, wasps, bugs, flies, grasshoppers, and spiders make up the rest. The vegetable food is composed of seeds, largely those of pines, with a few of the poison ivy and some weeds. There are few more useful birds than the chickadees.

Cooper's Hawk

The Cooper's hawk, or "blue darter," as it is familiarly known throughout the South, is a poultry- and bird-eating species, and its destructiveness in this direction is surpassed only by that of the goshawk, which occasionally in autumn and winter enters the United States from the North in great numbers. The general opposition to birds of prey is largely due to the activities of these two birds, assisted by a third, the sharp-shinned hawk, which in habits and appearance might well pass for a small Cooper's hawk. These birds usually approach under cover and drop upon unsuspecting victims, making great inroads upon poultry yards and game preserves. This destructive hawk, together with its two near relatives, should be destroyed by every possible means.

Crow

The general habits of the crow are universally known. Its ability to commit such misdeeds as pulling corn and stealing eggs and fruit and to get away unscathed is little short of marvelous. Much of the crow's success in life is due to coöperation. The winter roosts are sometimes crowded by hundreds of thousands of crows. From these roosts daily flights of many miles are made in search of food.

Injury to sprouting corn is the most frequent complaint against crows, but by coating the seed grain with coal tar most of this damage may be prevented. Losses of poultry and eggs may be averted by proper housing and the use of wire netting. The insect food of the crow includes wireworms, cutworms, white grubs and grasshoppers, and during outbreaks of these insects the crow renders good service. The bird is also an efficient scavenger. But chiefly because of its destruction of beneficial wild birds and their eggs the crow must be classed as a criminal.

Crow Blackbird (Grackle)

Most Americans are acquainted with the crow blackbird, a bird somewhat larger than a robin, with a long wedge-shaped tail. One species, il-

lustrated on Page 237, is the purple grackle. It occurs in the eastern United States. Another species, the bronzed grackle, is found throughout the United States east of the Rockies. The male grackle has iridescent, metallic plumage; that of the female is less brilliant.

The croaking, wheezing whistle of crow blackbirds has been compared to the sound of a cart wheel in need of grease. The birds are sociable and always live in flocks. As a charge against them it must be admitted that they often rob cornfields and sometimes destroy the eggs and young of smaller birds. On the other hand, they destroy great quantities of insects; they often devour grasshoppers in a wholesale manner.

Downy woodpecker

This woodpecker is commonly distributed, living in woodland tracts, orchards and gardens. The bird has several characteristic notes, and, like the hairy woodpecker, is fond of beating on a dry tree branch a tattoo which to appreciative ears has the quality of woodland music. In a hole dug in a dead branch the downy woodpecker lays from four to six eggs.

The downy and the hairy woodpeckers are among our most valuable allies, their food consisting of some of the worst foes of orchard and woodland, which the woodpeckers are especially equipped to dig out of dead and living wood. The animal food consists largely of beetles that bore into timber or burrow under the bark. Caterpillars amount to sixteen per cent of the food and include many especially harmful species. Grasshopper eggs are freely eaten. The vegetable food of the downy woodpecker consists of small fruit and seeds, mostly of wild species. It distributes seeds of poison ivy, or poison oak, which is about the only fault of this very useful bird.

English sparrow

Almost everywhere condemned since its introduction into the United States, the English sparrow has not only held its own, but has ever increased in numbers in spite of all opposition.

Courtesy Eastman Kodak Co.

FLICKER

This valuable bird friend is also known as the yellow-hammer and the highhole.

Its habit of driving out or even killing more beneficial birds and the defiling of buildings by its droppings and by its own unsightly nests, are serious objections to this sparrow. Moreover, in rural districts it is destructive to grain, fruit, peas, beans and other vegetables.

Flicker

The flicker inhabits the open country rather than the forest and delights in park-like regions where trees are numerous and scattered. It nests in any large cavity in a tree and is glad to use a box. It is possible, therefore,

to insure the presence of this useful bird about the farm and to increase its numbers.

It procures much of its food from the ground. The largest item of animal food is ants, of which the flicker eats more than any other common bird. Bugs are not largely eaten by the flicker. Wild fruits are next to ants in importance in the flicker's food list. Of these sour gum and wild black cherry stand at the head. The food habits of this bird are such as to recommend it to complete protection.

House wren

The rich, bubbling song of the familiar little house wren is one of the sweetest associations connected with country and suburban life. Its tiny body, long bill, sharp eyes, and strong feet peculiarly adapt it for creeping into all sorts of nooks and crannies where lurk the insects it feeds on. A cavity in a fence post, a hole in a tree, or a box will be welcomed alike by this busybody as a nesting site. But since the advent of the quarrelsome English sparrow such homes are at a premium and the wren's eggs and family are safe only in cavities having entrances too small to admit the sparrow. Hence it behooves the farmer's boy to provide boxes the entrances to which are about an inch in diameter, nailing these under gables of buildings or in orchard trees. In this way the numbers of this useful bird can be increased, greatly to the advantage of the farmer.

Grasshoppers, beetles, caterpillars, bugs and spiders are the principal articles of its food. The nestlings of house wrens consume great quantities of insects.

Killdeer

The killdeer is one of the best known of the shorebird family. It often visits the farmyard and commonly nests in pastures or cornfields. It is rather suspicious, however, and on being approached takes flight with loud cries. It is noisy and restless, but fortunately most of its activities result in benefit to man.

The food is of the same general nature as that of the upland plover, but is more varied. The killdeer feeds upon beetles, grasshoppers, caterpillars, ants, bugs, caddis flies, dragonflies, centipedes, spiders, ticks, oyster worms, earthworms, snails, crabs and other crustacea. Among the beetles consumed are such pests as the alfalfa weevil, cotton-boll weevil, clover-root weevil, cloverleaf weevil, pine weevil, billbugs, white grubs, wireworms and leaf beetles. The bird also devours cotton worms, cotton cutworms, horseflies, mosquitoes, cattle ticks, and crawfish. One stomach contained hundreds of larvae of the salt-marsh mosquito, one of the most troublesome species. The killdeer preys extensively upon insects that are annoying to man and injurious to his stock and crops, and this should be enough to remove it from the list of game birds and insure its protection.

Kingbird

The kingbird is an enemy of hawks and crows, which it vigorously attacks at every opportunity, thereby affording protection to near-by poultry yards and young chickens at large. It prefers the open country and is especially fond of orchards and trees about farm buildings.

No less than eighty-five per cent of its food consists of insects, mostly of a harmful nature. It eats the common rose chafer or rose bug, and more remarkable still it devours blister beetles freely. The bird has been accused of eating honeybees to an injurious extent, but there is little

BIRDS OF PREY AND GAME BIRDS

KING BIRD

SPARROW HAWK

COOPERS HAWK

BOB WHITE

RUFFED GROUSE

RED TAILED HAWK

PLOVER

SCREECH OWL

BARN OWL

ground for the accusation. On the other hand, it devours robber flies, which catch and destroy honeybees. Grasshoppers and crickets, with a few bugs and some cutworms, and a few other insects, make up the rest of the animal food. The vegetable food consists of fruit and a few weeds. The kingbird deserves full protection.

Meadowlark

Our two meadowlarks, though differing much in song, resemble each other closely in plumage and habits. Grassy plains and uplands covered with a thick growth of grass or weeds, with near-by water, furnish the conditions best suited to the meadowlark's taste. The song of the western bird is loud, clear and melodious. That of its eastern relative is feebler and loses much by comparison.

In many localities the meadowlark is classed and shot as a game bird. From the farmer's standpoint this is a mistake, since its value as an insect eater is far greater than as an object of pursuit by the sportsman. Both the boll weevil, the foe of the cotton grower, and the alfalfa weevil are among the beetles it habitually eats. Twenty-five per cent of the diet of this bird is beetles, half of which are predacious ground beetles, accounted useful insects and one-fifth are destructive weevils. Caterpillars form eleven per cent of the food and are eaten in every month in the year. Among these are many cutworms and the well-known army worm. Grasshoppers are favorite food and are eaten in every month and almost every day. The vegetable food (twenty-four per cent of the whole) consists of grain and weed seeds.

Mocking-bird

Because of its incomparable medleys and imitative powers, the mocking-bird is the most renowned singer of the Western Hemisphere. Even in confinement it is a masterly performer, and formerly thousands were trapped and sold for cage birds, but this practice has been largely stopped by protective laws. It is not surprising, therefore, that the mocking-bird should receive protection principally because of its ability as a songster and its preference for the vicinity of dwellings. Its place in the affections of the South is similar to that occupied by the robin in the North.

About half of its diet consists of fruit, and many cultivated varieties are attacked, such as oranges, grapes, figs, strawberries, blackberries and raspberries. Somewhat less than a fourth of the food is animal matter, and grasshoppers are the largest single element. The bird is fond of cotton worms, and is known to feed also on the chinch bug, rice weevil and boll-worm. It is unfortunate that it does not feed on injurious insects to an extent sufficient to offset its raids on fruit.

Mourning dove

The food of the mourning dove is practically all vegetable matter (over ninety-nine per cent), principally seeds of plants, including grain. Wheat, oats, rye, corn, barley and buckwheat were found in 150 out of 237 stomachs, and constituted thirty-two per cent of the food. Three-fourths of this was waste grain picked up after harvest. The principal and almost constant diet is weed seeds, which are eaten throughout the year and constitute sixty-four per cent of the entire food. In one stomach were found 7,500 seeds of yellow wood sorrel, in another 6,400 seeds of barn grass or foxtail, and in a third 2,600 seeds of slender paspalum, 4,820 of orange hawkweed, 950 of hoary vervain, 120 of Carolina cranesbill, 50 of

yellow wood sorrel, 620 of panic grass, and 40 of various other weeds. None of these is useful, and most of them are troublesome weeds. The dove does not eat insects or other animal food. It should be protected in every possible way.

Nighthawk

The skillful movements of a company of nighthawks as they gracefully cleave the air in circles is a sight to be remembered. So expert are they on the wing that no insect is safe from them, even the swift dragonfly being captured with ease. Unfortunately their irregular flight tempts men to use them for targets, and this practice is seriously diminishing their numbers, which is unfortunate, since no birds are more useful. The nighthawk makes no nest, but lays its two spotted eggs on the bare ground, sometimes on the gravel roof of the city house.

It is a greedy feeder and eats insects almost exclusively. From 500 to 1,000 ants are often found in a nighthawk's stomach. Several species of mosquitoes, including *Anopheles*, the transmitter of malaria, are eaten. Other well-known pests destroyed by the nighthawk are the Colorado potato beetle, cucumber beetles, cloverleaf and cotton-boll weevils, billbugs, bark beetles, squash bugs, and moths of the cotton worm.

Purple martin

This is the largest as it is one of the most beautiful of the swallow tribe. It formerly built its nests in cavities of trees, as it still does in wild districts, but learning that man was a friend it soon adopted domestic habits. Its presence about the farm can often be secured by building houses suitable for nesting sites and protecting them from the English sparrow. Every effort should be made to increase the number of colonies of this very useful bird. The boxes should be at a reasonable height, say fifteen feet from the ground, and made safe from cats.

A colony of these birds on a farm makes great inroads upon the insect population: the birds not only themselves feed upon insects but rear their young upon the same diet. Fifty years ago in New England it was not uncommon to see colonies of fifty pairs of martins, but most of them have now vanished for no apparent reason except that the martin houses have decayed and have not been renewed. More than three-fourths of this bird's food consists of wasps, bugs, and beetles, their importance being in the order given. The beetles include several species of harmful weevils, as the clover-leaf weevils, and the nut weevils. Besides these are many crane flies, moths, May flies and dragonflies.

Red-tailed hawk

The red-tailed hawk, or "henhawk," as it is commonly called, is one of the best known of all our birds of prey, and is widely distributed. Its habit of sitting on some prominent limb or pole in the open, or flying with measured wing beat over prairies and sparsely wooded areas on the lookout for its favorite prey, causes it to be noticed easily.

It feeds on a variety of food, as small mammals, snakes, frogs, insects, birds, crawfish, centipedes, and even dead bodies. In regions where rattlesnakes abound it destroys considerable numbers of the reptiles. Although it feeds to a certain extent on poultry and birds, it is nevertheless entitled to general protection on account of the steady warfare it wages against field mice and other small rodents and insects that are so destructive

to young orchards, nursery stock and farm produce.

Red-winged blackbird

The prairies of the upper Mississippi Valley, with their numerous sloughs and ponds, furnish ideal nesting places for red-wings, and consequently this region has become the great breeding ground for the species. These prairies pour forth the vast flocks that play havoc with grainfields. East of the Appalachian Range, marshes on the shores of lakes and rivers are the only available breeding sites and, as these are comparatively few and small, the species is much less abundant than in the West. Red-wings live in flocks and breed in communities.

The food of the red-wing consists of twenty-seven per cent animal matter and seventy-three per cent vegetable. Insects constitute practically one-fourth of the food. Beetles (largely weevils, a most harmful group) amount to ten per cent. Grasshoppers are eaten in every month and amount to about five per cent. Caterpillars (among them the injurious army worm) are eaten at all seasons and amount to six per cent. Ants, wasps, bugs, flies, dragonflies and spiders also are eaten. The vegetable food consists of seeds, including grain (of which oats is the favorite) and some small fruits. When in large flocks this bird is capable of doing great harm to grain.

Robin

In the North and in some parts of the West the robin is among the most cherished of our native birds. Should it ever become rare where now common, its joyous summer song and familiar presence will be sadly missed in many a homestead.

The robin is a greedy feeder, and its food includes many orders of insects, with no very special preference for any. It is very fond of earthworms. Its vegetable food amounts to about fifty-eight per cent of all; the principal item is fruit, which forms more than fifty-one per cent of the total food. The fact that in an examination of over 1,200 stomachs the percentage of wild fruit was found to be five times that of the cultivated varieties suggests that berry-bearing shrubs, if planted near the orchard, will serve to protect more valuable fruits. In California in certain years it has been possible to save the olive crop from hungry robins only by the most strenuous exertions and considerable expense. The bird's general usefulness is such, however, that all reasonable means of protecting orchard fruit should be tried before killing the birds.

Rose-breasted grosbeak

This beautiful grosbeak is noted for its clear, melodious notes, which are poured forth in generous measure. It sings even at midday during summer, when the intense heat has silenced almost every other songster.

Its beautiful plumage and sweet song are not its sole claim on our favor, for few birds are more beneficial to agriculture. It eats some green peas and does some damage to fruit. But this mischief is much more than balanced by the destruction of insect pests. The bird is so fond of the Colorado potato beetle that it has earned the name of "potato-bug bird," and no less than a tenth of the total food examined consisted of potato beetles—evidence that the bird is one of the most important enemies of the pest. It vigorously attacks cucumber beetles and many of the scale insects. It proved an active enemy of the Rocky Mountain locust during that insect's ruinous invasions. Among the other pests it consumes are the spring and fall cankerworms, orchard

and forest tent caterpillars, tussock, gipsy, and brown-tail moths, plum curculio, army worm, and chinch bug; in fact, not one of our birds has a better record.

Ruffed grouse

The ruffed grouse, the famed drummer and finest game bird of the northern woods, is usually wild and wary and under reasonable protection well withstands the attacks of hunters. Moreover, when reduced in numbers, it responds to protection in a gratifying manner.

Wild fruits, nuts, and green sprouts make up the bulk of the vegetable food of this species. It is very fond of hazelnuts, beechnuts, chestnuts and acorns, and it eats practically all kinds of wild berries and other fruits. Various weed seeds also are consumed. Slightly more than ten per cent of the food consists of insects, about half being beetles. The most important pests devoured are the potato beetle, clover-root weevil, the pale-striped flea beetle, grapevine leaf-beetle, May beetles, grasshoppers, cotton worms, army worms, cutworms, the red-humped apple worm and sawfly larvae. While the food record of the ruffed grouse is fairly praiseworthy, it does not call for more protection than is necessary to keep the birds in reasonable numbers.

Screech owl

The little screech owl inhabits orchards, groves and thickets, and hunts for its prey in such places as well as along hedge rows and in the open. During warm spells in winter it stores up in some hollow tree quantities of food for use during bad weather. Such larders often contain enough mice or other prey to last it over a week or more. With the exception of the burrowing owl it probably eats more insects than any other nocturnal bird of prey. It feeds on small mammals, birds, reptiles, batrachians, fish, spiders, crawfish, scorpions and earthworms. Grasshoppers, crickets, ground-dwelling beetles, and caterpillars are its favorites among insects, as are field mice among mammals and sparrows among birds. The screech owl should be encouraged to stay near barns and outhouses, as it will keep in check house mice and wood mice, which frequent such places.

Sparrow hawk

The sparrow hawk lives in the more open country and builds its nest in hollow trees. It is abundant in many parts of the West, where telegraph poles afford it convenient perching and feeding places.

Its food consists of insects, small mammals, birds, spiders and reptiles. Grasshoppers, crickets and terrestrial beetles and caterpillars make up considerably more than half its subsistence, while field mice, house mice, and shrews cover fully twenty-five per cent of its annual supply. The balance of the food includes birds, reptiles and spiders. Contrary to the usual habits of the species, some individuals during the breeding season capture nestling birds for food for their young and create considerable havoc among the songsters of the neighborhood. In agricultural districts when new ground is broken by the plow, they sometimes become very tame, even alighting for an instant under the horses in their endeavor to seize a worm or insect. This little hawk renders good service in destroying harmful insects and rodents and should be encouraged and protected.

Upland plover

This, the most terrestrial of our waders, is shy and wary, but it has

BIRDS NOTED FOR SONG OR PLUMAGE

BLUE JAY

ROBIN

WOODPECKER

BOBOLINK

MOCKING BIRD

MEADOW LARK

GROSBEAK

THRUSH

BLUE BIRD

the one weakness of not fearing men on horseback or in a vehicle. One of these methods of approach, therefore, is nearly always used by the sportsman, and, since the bird is highly prized as a table delicacy, it has been hunted to the verge of extermination.

As the upland plover is strictly beneficial, it should no longer be classed as a game bird and allowed to be shot. Ninety-seven per cent of the food of this species consists of animal forms, chiefly of injurious and neutral species. The vegetable food is mainly weed seeds. Almost half of the total subsistence is made up of grasshoppers, crickets and weevils. Among the weevils eaten are the cotton-boll weevil, greater and lesser clover-leaf weevils, cowpea weevil, and billbugs. This bird devours also leaf beetles, wireworms, white grubs, army worms, cotton worms, cotton cutworms, sawfly larvae, horseflies and cattle ticks. In brief, it injures no crop, but consumes a host of the worst enemies of agriculture.

YELLOW-BELLIED SAPSUCKER

Rather silent and suspicious, the sapsucker generally manages to have a tree between itself and the observer. Hence the bird is much better known by its works than its appearance. The regular girdles of holes made by this bird are common on a great variety of trees; in all about 250 kinds are known to be attacked. Occasionally young trees are killed outright, but more loss is caused by stains and other blemishes in the wood which result from sapsucker punctures. These blemishes, which are known as "bird pecks," are especially numerous in hickory, oak, cypress and yellow poplar. Defects due to sapsucker work cause a great annual loss to the lumber industry.

The food of the yellow-bellied sapsucker is about half animal and half vegetable. Its fondness for ants counts slightly in its favor. It eats also wasps, beetles (including, however, very few wood-boring species), bugs and spiders. The two principal parts of the vegetable food are wild fruits of no importance and cambium (the layer just beneath the bark of trees). In securing the cambium the bird does the damage above described. The yellow-bellied sapsucker, unlike other woodpeckers, thus does comparatively little good and much harm.

GENIAL EXPRESSION

This interesting photographic study of a rabbit was made by Dr. Bigelow, the author of the following article.

PLAYMATES

SOME FOUR-FOOTED FRIENDS

(INTIMATE STORIES BY A NATURALIST)

IN MY boyhood I lived alone on a farm with no near neighbors so far as companions of my own age were concerned. My chief playmates were four-footed animals, and early in life I came to realize their friendliness and personality.

Animals are worthy of admiration and interest. They are extremely entertaining, but they should never be idolized or worshiped. Neither should their mental attainments be exaggerated. I cannot agree with the claim of some enthusiastic naturalists that the mentality of four-footed animals differs from that of human beings only in degree. From that point of view it would be easy to compare some of our most intelligent animals—dogs and elephants, for example—with some human beings.

Of course, our four-footed friends at times do things that might easily be considered as acts of human intelligence. In matters of love and loyalty some pets, notably the dog, even excel the friendships of some human beings. The dog adores his master and will share with apparent gladness even lack of food and shelter. The companionship and appreciation of his master seems to be all-sufficient.

I want to tell in this article about some four-footed animals that have

A FAITHFUL FRIEND

The loyalty of the dog even excels the friendship of some human beings.

interested me and been associated with me in various stages of my life. I mention the animals partly in the order of my experiences with them, and partly in the order of my preference. In a certain sense it would seem hard to prefer a skunk to a modern long-haired cat, and weasels are nowhere near as lovable as cavies and

WOODCHUCK

One of the author's interesting pets. In winter the woodchuck goes into a long sleep.

pet rabbits; but the wild weasels, woodchucks, skunks and cottontail rabbits cling closer to my heartstrings than do many modern, conventional pets.

Dogs

I pay tribute first of all to Daisy, my shepherd dog. Daisy understood the farm, how to drive cattle and sheep and how to hunt squirrels, birds and butterflies, but she never knew how to go with the gun. There was an ancient myth that when Daisy was a puppy she was accidentally wounded by a former owner while he was handling a gun. At any rate she was, unlike any other dog I have seen, greatly afraid of a gun. While this was a decided disadvantage, it deepened my appreciation of her personality and of whatever in her past life had produced this fear.

As we started for the woods she ran ahead of me with a sprightly cavorting manner and a look that seemed to say, "I love you in spite of your gun, but sooner or later you must decide which you are going to take—that gun or this dog." Arriving at the woods, she would fool me. Apparently a better hunting dog never barked a squirrel up a tree, and she went tearing through the woods as if saying, "There goes another," and then that was all I saw of her until I found her at home at night. She never got beyond the beginning of the hunt with a gun, but for hunting woodchucks she was "just great."

Woodchucks

Every naturalist, notably John Burroughs, goes into ecstasies over the woodchuck, for it is indeed the most tantalizing of all the wild four-footed animals. It is also the most ludicrous as it waddles away and turns heels over head into its burrow.

Fool a woodchuck Why, that animal apparently sits up—at a safe distance—and says, "Try it. I will match my wits with yours."

The shrill whistle of a woodchuck within a stone wall is the most inspiring of calls to boy or dog. Both "go crazy." The boy pulls down that wall at a rate inspired by his feeling that he must keep at least apace, if not ahead, of the jumping and barking of the dog.

But I never really knew the woodchuck until a little girl arrived at our

front door holding tightly in her hands a little fellow she had found in a near-by clover field. We kept that woodchuck for two years—sometimes in the office, sometimes in the pet house—and in its hibernation displayed it to puzzled but admiring visitors. "What is hibernation?" they inquired. I always answered, "I do not know. The little animal is still alive, and yet it seems not exactly to be asleep."

Yes, I have dug woodchucks out of stone walls, and things are all right when it *is* a woodchuck, but there is terrible trouble when it happens to be a skunk.

Skunks

Dig a series of holes, expecting to find the burrow of the woodchuck you are after—and you do not. After meeting the full blast of "perfume," I found a bed, for grandmother insisted she must wash my one suit of shirt and overalls. Of course, Daisy could go to the brook and then run diagonally on the grass with open mouth as if that were the worst dose of medicine she had ever received.

The queer fact is that the more smelly the skunks the more some naturalists—and especially my friend, Ernest Thompson Seton—seem to like them. Call upon Mr. Seton, at his home in Greenwich, and he entertains even the young ladies by handing them what he calls a "lovely skunk," explaining that the ladies should admire the beauty of the skunk and, incidentally, will not need to buy any perfume for a month or so. Now I am perfectly willing to let him have his skunks. I do love a skunk—a long, long way off. But the skunk has one admirable quality, and that is its perfect confidence in its own ability to possess the entire field. In my boyhood I never disputed that question even if I had to climb a tree to get out of the way.

The skunk is less wild than any other so-called wild creature. When caught in a box trap it is apparently somewhat tame from the first. I have seen naturalists handling skunks that they claimed were the day before running wild in the woods. When my friends go into raptures of delight in skunks, I think: "What is the use of getting into a quarrel with other naturalists? Why not take their word for it?"

SKUNKS
Just take the skunks by "the handle."

Raccoons

I have a lifelong apology to make to the raccoons. I went hunting once with two boys from the academy. They said they were after blue jays' wings and wanted to try a shot at a squirrel's nest. I happened to be in just the right position to bring the so-called squirrel's nest between the

BRINGING UP A RACCOON
Zippa, the baby raccoon, enjoying her bottle. If it did not appear on time she would cry for it.

sun and me. I saw it was not sticks and leaves, but fur. "Fellows, that's a raccoon. I have heard about raccoons, but never before have I seen one curled up like a squirrel's nest." We banged away and after some difficulty killed the coon. Then I asked the others, "Why do people go coon hunting?"

I take it all back. I did go later, and had the best kind of hunting. I found a little one among the stones in Roaring Brook at Meriden, Connecticut, and brought it home in my hat. Uncle Dan used to sing a song about Old Zip Coon, and I wanted to call this one Zip, but Zippa seemed better to fit her femininity.

Zippa cried like a baby, and mostly for the same thing—her nursing bottle. As with the little child, she was all ours for a few weeks, and then came the longing to leave home. And one day she did—into the fairyland of the top of the pet house, and only gingerbread tempted her back. O boys and girls, if you have never had a pet coon you have missed one of the joys of life! What fun to see it eat buttered toast, and to watch it put its paw into molasses and then lick it!

Raccoons eat a wide range of food, but always wash the food before eating, and afterwards themselves. They are lovers of water. All sorts of expressions can be read in the twinkling of its eyes, as a raccoon looks at you in a mischievous way.

Squirrels

Yes, I have many a time shot squirrels but never shall do so again. There was a day when it was perfectly proper to shoot them, but I think that day has passed. At least in our vicinity, even the gray squirrel is not present in sufficient quantities ever to be a pest. I seldom see a red squirrel and only occasionally a chipmunk. We are in the central part of the village, yet almost any time we can see a half dozen gray squirrels scampering around the grounds here at ArcAdiA, at Sound Beach, Connecticut. Even in the old boyhood days on the farm I never saw as many as six squirrels at one time. Dr. Hornaday has recently stated that squirrels have deserted the forests in Connecticut and gone into the villages, because in the villages the people protect these little animals more efficiently than the laws protect them in the woods.

Squirrels bury nuts in the leaves and leaf mold in the wild woods. To some extent they do so here at ArcAdiA, but they also have the curious notion that an excellent place to tuck in the walnuts is the doormat. It is made of

SQUIRREL

This active, graceful animal is a close relative of the woodchuck.

rope material with little bunches of bristles that stick up and seem, perhaps, to invite the squirrels to hide their treasure.

In our astronomical observatory there is, under the eaves of the rolling roof, an opening to keep the temperature and atmosphere the same as outdoors. The squirrels go into the observatory through this opening and build their nests of sticks, leaves and fine fibers of bark. For protection we keep a pillowcase on one end of the telescope. But the squirrels evidently think it is put there for their play. One pillowcase was entirely chewed up and I jumped to the conclusion they had used it for nest lining, but when I pulled down the nest not a bit of it was there. I put up another pillowcase and they never chewed that at all but tore it to pieces. I wish some thinker would tell me why.

WILD RABBITS

In the early stages of its life, the little cottontail is well cared for by the mother, who even tears off her own fur for the nest lining. When I discovered that, I caught no more rabbits. I could not kill animals capable of such sacrifices.

This mother, though out in the open woods, is often found and bothered by dogs. Yet how is it that she can build right in the central part of a village, and in some cases near where there are plenty of dogs, and never a dog find that nest? A dog has an extremely keen scent for a rabbit, so much so that even if in its serious business of chasing the rabbit it should pause to dig up an odorous skunk as a recreation, it can immediately take up the rabbit scent and go on with the chase.

WILD RABBITS *Courtesy Eastman Kodak Co.*

The wild rabbit protects itself by keeping perfectly still and motionless.

Once I was photographing the tops of trees by means of a tilting camera pointed upward all the time. I had not a chance to look down at the ground. Imagine my surprise at finding, after some fifteen minutes' work, a cottontail crouching near my feet in

OPOSSUM
He seems to say that he can appreciate a joke.

plain sight in the base of a hollow tree. That is the way the rabbit protects itself—by keeping perfectly still and motionless.

Opossums

In all my life I never told a joke to an opossum, but I have never seen one that did not have a perpetual grin as if he had just heard a very funny story. And the opossum apparently can appreciate a joke, because for a time it will play dead, and then, of a sudden, if you happen to go over or through a fence with one in your hand and its claws touch the rail, it clings there in a manner not at all becoming to a dead opossum. If reprimanded by being pulled away from the rail he seems to say, "I think I know all the rights and wrongs of being dead." It makes me think of the hognose snake that curls up, turns on its back and pretends to be dead. If you pick up that snake and turn it over just as it lies, it will immediately and quickly turn over again, without uncoiling, as if to say, "I know the position in which a dead snake should—literally—'lie.'"

Weasels

Do I love *all* four-footed animals? No. The weasel I hate. Excuse me—I take it back. Of course, in a certain sense, one loves all forms of life, looked at from their interesting characteristics. But, looked at from the human point of view, the weasel is about the biggest example of meanness that ever walked on four legs. I can understand an animal killing when hungry, but the weasel kills for deviltry. It will, in a short time, wreck a henhouse or kill innumerable small animals, merely taking a little taste of the blood of each without doing full justice even to that. It seems to delight in being ugly. If it had not been for John, a weasel would have grabbed my bare big toe as I was sitting on a rail fence. I just happened to be wiggling my toe, and I suppose the weasel thought it was a challenge to come out and get it.

It is predicted that weasels, especially in their white winter coat, the valuable ermine, will be exterminated by the demand. Even at present they are not common.

Minks

Minks have the same bloodthirsty qualities but do not go to such an extent in killing merely for the sake of killing. I have been told by naturalists that the minks are widely scattered over this country, each one ranging over considerable territory. They seem to have learned to limit killing activities to somewhere near actual

need. They are large enough to make their fur of considerable value.

Cats

If cats would only reform and become less injurious to wild birds, I could give them my unlimited approval, because the cat, perhaps more than any other form of life, is won by a touch of affection and apparently appreciates it. The dog seems to be won not so much by affection as mastery, and that secondarily develops affection. You can insist on the obedience of the dog but not so with the cat. They are won only by love and kind dealing. Perhaps that is the reason they endear themselves so strongly to many people. The friendship of a cat is much more fickle than that of a dog. The cat takes up with any one who feeds and pets it, but dogs, notably police dogs, make but few friendships.

Tame rabbits

I have already told you of some of my experiences and impressions with wild cottontail rabbits, but now I come to an entirely different type—those kept as pets and for fur and food, the home rabbits.

Which do I like best? I think I give first premium to the so-called butterfly or checkered rabbits. They are spotted much as an English coach dog and have a large spot on the end of the nose. With a little imagination one might say that spot looks like a butterfly.

THE KITTEN POSES

The cat is won by a touch of affection and seems to appreciate it.

Next in my appreciation is the Himalayan with the curious black markings and gentle movements.

TAME RABBITS

Blue Dutch and her babies. Because of their markings, these rabbits seem to be wearing trousers and shirtwaists.

For a real pet, I like the Dutch rabbit, either the blue or the black. These are trousered fellows with interesting shirtwaists.

I would like all forms of domestic rabbits much better than I do if they were interested in anything but eating. They have made a monopoly of life's interests in that.

If, boys and girls, you want to keep rabbits, get the good ones. I do not consider the ordinary white, pink-eyed, everyday rabbit the most desirable. It takes no more time and expense to feed and care for a really good rabbit than a poor one. Several publications in this country are devoted to small pet stock and these will tell you where to obtain the better rabbits and how to care for them.

Cavies

Closely associated with rabbits are cavies. Most rabbit fanciers have a few cavies and the cavy specialist likes a few rabbits. They go well together in the same building but not in the same hutch (pen).

Who ever coined that foolish term, guinea pig? They do not come from Guinea and they are not pigs. The generally accepted term of cavy is far better.

They will stand more handling than rabbits. One has to know just how to handle a rabbit, especially a little one, in order not to injure or kill it. Do not pick it up by the ears. The best way is to let it sit in the cage as you look at it.

A skilled humorist once wrote a story, "Pigs is Pigs," and carried the idea that cavies, miscalled guinea pigs, are very easy to breed. I have not found this to be the actual situation, and other fanciers have also sometimes had difficulties in breeding.

Cavies have never been popular with the mass of pet lovers. They are limited to the few enthusiasts, but let one get the fever of cavy enthusiasm and it strikes hard. It has so taken hold of some business men that they have paid as much as a hundred dollars or even more for a single cavy having an unusual point or appealing especially to the buyer.

Mice

Many persons have tried to discover perpetual motion. The one who keeps waltzing mice pretty nearly has it. You have heard about a dog chasing its tail as the symbol of aimlessness. But no dog in this world ever chased its tail as furiously as does a waltzing mouse. It turns so fast that it looks like a revolving top.

In the matter of rabbits I must harbor no grudge against pink eyes and white fur in themselves, for I should have to take it all back when it comes to mice. White mice are indeed extremely clean, and, to our delight, spend most of their time in scrubbing face and hands.

A loaf of bread makes a good home for white mice. As they eat the bread they tunnel into the loaf and make their home there. Of course there should be kept in the cage nesting material that the mice may carry into their home. Mice will use almost any kind of material, such as paper, cloth, strings and plant fibers.

So, girls and boys, I have given suggestions about some of the most interesting of our pets, but I have not pointed out a hundredth part of the entertaining things they do and of the fun you can have in caring for them.

When some one asks which pet I like best I think of Henry David Thoreau, who was asked in the midst of a conversation which piece of the chicken he preferred. Thoreau briefly replied: "The nearest," and went on with what he was saying.

ENTRANCE TO THE NEW YORK ZOÖLOGICAL PARK

WILD ANIMALS AT THE ZOO

A STUDIOUS visit to a large zoölogical park gives a view of a miniature world of wild animals and animal houses. In the creation of it, several thousand persons have combined their thought, their energy and their money.

Their first task was to prepare comfortable homes for the beasts, birds and reptiles. After that, in the far distant jungles and plains, in the forests, in the mountains and on the seashore, strange men with white, black, brown and yellow faces toiled, and at times risked their lives, to capture and transport living examples of the most wonderful and most beautiful creatures, actually to our door, for our instruction.

In beholding the wild animals of a great zoo, we must pause occasionally and reflect upon the difficulties that have been overcome in assembling, housing and keeping those habitants of so many climes and altitudes, all in one spot, in the cause of human education. The 2,536 living vertebrates (back-boned animals) of the New York Zoölogical Park demand 124 different kinds of food.

A modern zoölogical park is not an assemblage of suffering prisoners, kept in cramped quarters. The sight of unhappy animals never is pleasing to the public. Animals that cannot be kept in comfortable and reasonably happy captivity should not be kept at all. Very few of the important mammals or birds of a zoo are caught when fully grown and accustomed to wild freedom. Most of them are caught when very young, knowing little of the free wild life, and unaccustomed to struggle every waking hour to avoid their enemies, and to secure food and water without being killed.

In the modern zoo, wild animals are humanely housed, cared for, doctored when ill, and carefully shielded from annoyances. When this is true it is right that they should do their share in educating mankind in wild-animal lore. For men and for animals, this world is full of work, and of duties to be performed. One thing to be discouraged is the efforts of inexperienced or cruel persons to keep living creatures without proper means, or proper knowledge. No one should try to care

for a wild animal unless he can give it suitable attention.

How classification helps us to understand animals

The young student who for the first time enters a wild-animal world as seen in a large zoölogical park, possibly may feel bewildered by the array of strange forms. But there is no reason for discouragement. There is a wonderful master key, good for the whole animal kingdom. It is called "Classification."

Classification in accordance with the great system of nature furnishes the foundation for all zoölogical knowledge. The Classes represent the cities of zoölogy; the Orders represent the city blocks; the Families represent the buildings; the Genera represent the different floors, and the Species the rooms. As well might a library try to exist without catalogues and shelves as zoölogy without adequate classification according to natural laws.

Fortunately for us all, to the studious and inquiring mind zoölogical classification is an easy and delightful study. The first place in which to study it is the school classroom, with the aid of a good textbook; but the home student who is diligent also can master it reasonably well. In the zoo, the classroom, or the home, it is best to begin with the highest animals, and work downward to the lower forms.

The interesting order of apes, baboons and monkeys

To all races and conditions of men, the most interesting mammals are those composing the Order of Apes, Baboons and Monkeys (Primates), because in structure, minds and habits they stand nearest to man. The head and face, the hand and the foot of the red-haired orang-utan are just as wonderful to the brown-skinned Dyaks of Borneo as they are to the boys of Chicago. The humanlike intelligence of the black chimpanzee of Africa is almost equal to that of some of the lower tribes of men. The big, ugly and fierce baboons of Africa have survived and thriven in a land well stocked with lions, leopards and wild dogs, solely because of their wide jaws, their big and deadly canine teeth (which in adult males are formidable tusks), their fierce courage and their agility.

YOUNG GORILLA AND SCULPTOR
The sculptor is using a young live gorilla as a model.

THE MAN-EATERS OF TSAVO

These lions from British East Africa killed more than 120 natives before they themselves were killed and placed in the Field Museum of Natural History in Chicago.

Notice the strange East Indian swinging gibbon, that on the ground always and easily walks erect; the spider and howling monkeys of South America with tails powerfully made for grasping; the highly-colored Diana monkey of Africa, and the array of tiny marmoset monkeys of South America that look like nothing under the sun save themselves. The lemurs of Madagascar probably were the first Primates to branch off by themselves toward higher development.

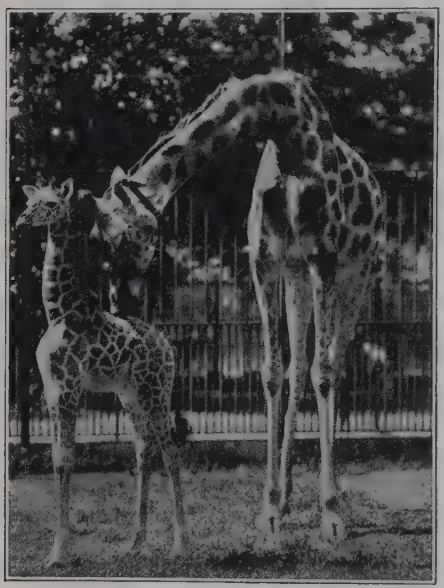
The Flesh-Eaters

The great Order of Carnivora (flesh-eaters) begins in the Lion House, with his majesty the king—but it does not by any means end there. Of all lions, the black-maned individuals of northern Africa are considered the handsomest. Conscious of their power for defense or offense, they are the most noble, dignified and steady-nerved of all the large, catlike animals. The lioness of the zoo is no larger than the two famous "man-eaters of Tsavo," British East Africa, which killed and ate more than 120 native workers before they themselves were killed, and mounted, and placed in the Field Museum of Natural History in Chicago.

More than one American zoo exhibits long-haired and massive Siberian tigers, alongside the big, short-haired Bengal and the slender Sumatran type. The burly bulldog jaguar of Central and South America is the largest and most dangerous spotted cat of America, and of it the ocelot is properly regarded as a diminutive relative. The leopard of the Old World is beautiful, but usually bad tempered and dangerous. The beautiful snow leopard of western China is hard to get and hard to hold. The American mountain lion, or puma, is the most agile climber of all the large cats, and it can scream as loud as a small boy.

In various places outside the great Lion House will be found the other families of flesh-eaters. In a sheltered valley is the picturesque array of bear

dens, with a fine series of big Alaskan brown bears, white polars, silver-tip grizzly bears from the Rocky Mountains, black bears from many places; hairy-eared bears from central Asia, the bad tempered little Malay sun bear, and the absurd sloth bear of India. Study the bears of the world; for they make a fine group, and their heads are full of wisdom.



GIRAFFES

Mother with baby born in New York Zoölogical Park. At birth the baby was 5 feet 6 inches high. It takes about ten years for a giraffe to reach a height of 14 feet, at which any giraffe may fairly be regarded as "full grown."

The wolf and fox dens contain the Dog Family. The wolves are the worst destroyers of cattle and game. No wolf nor hyena is beautiful. Of the foxes it is not safe to keep more than the common species. To exhibit in a big city a large and fine black fox with a pelt worth $500 or $1,000 would be a great temptation to a fox thief.

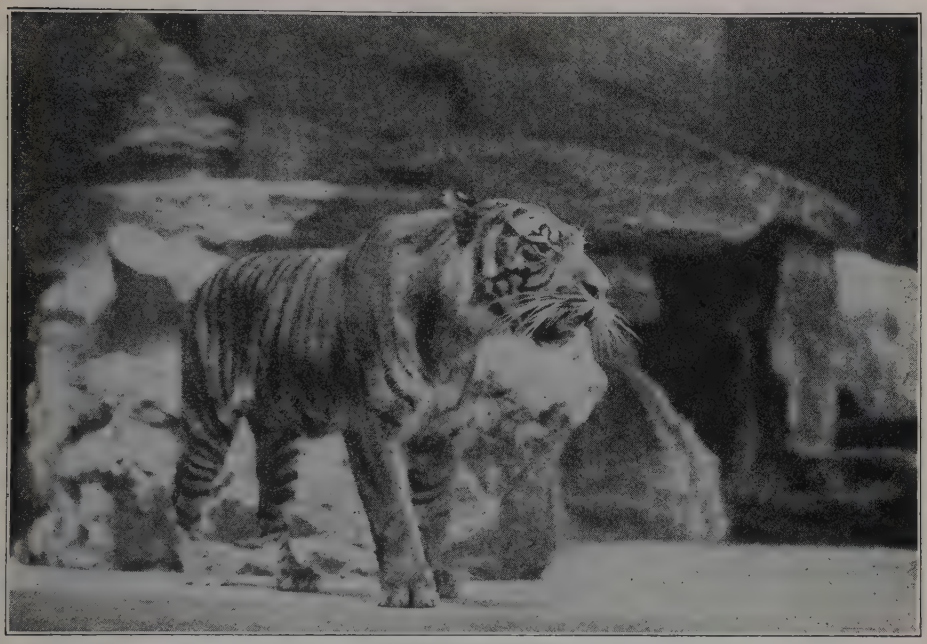
Of the Marten Family, the Civet Cat Family, and the other small flesh-eaters in the Small Mammal House, there is not time to speak. You may read about some of the fur-bearers in the next volume.

THE HOOFED ANIMALS

Leaving the fine Order of Carnivora, we will consider next the huge and highly important Order of Hoofed Animals, once called Ungulata (un-gew-lay′-tah), but now divided into the two-toed and many-toed orders. Never mind their Latin names just now. The first and largest group contains the Deer Family, the Camels, the Giraffes, the Antelopes, the Goats and Ibexes, the Sheep, the Musk-Oxen and the grand array of Bison, Buffaloes and Wild Cattle. Are not these names alone, of big animals and small ones, scattered through all lands and climes, enough to give any lover of animals real thrills? It should be a pleasure to study them at length.

The camel is often called "the ship of the desert," because it carries people and merchandise across the sandy deserts of Africa and Asia. There are two species, the true or Arabian camel, also called dromedary, with one hump, and the Bactrian camel, which has two humps. The hump is a store of flesh and fat which may be absorbed as food, thus allowing the animal to go for a long time without food. The llama of South America is also a member of the camel family.

Of the four or five giraffe species, found only in Africa, the Nubian is often seen in captivity, the others almost never. This is a pity, because of the striking character of the color patterns put upon some of them by the hand of nature. Strange to say, the remaining giraffes of Africa are now quite well protected from wanton slaughter, in great natural preserves and otherwise, and they may last for a century. Although ill-fitted in form for life on exhibition in captivity, the giraffes do well in zoos and large shows, and frequently breed and rear their young. The picture shows a seven-foot "baby" born in the New



SIBERIAN TIGER

Largest and most powerful of the cats. Naturalists believe that the tiger is not naturally a tropical species.

BACTRIAN CAMEL

The Arabian camel has but one hump, while the Bactrian has two. The llama of South America belongs to the camel family.

VIEW IN NATIONAL COLLECTION OF HEADS AND HORNS
Here in the New York Zoölogical Park is the finest collection of heads and horns in all the world.

York Zoölogical Park on July 17, 1924. It was later presented to the Ringling Brothers-Barnum and Bailey Circus. Another giraffe, born in 1929, is still living (1935) in the Park.

In any large zoo, these family groups of large animals occupy many buildings, and much ground in open "ranges" and "corrals." Make haste to bring them all firmly together in the Order of Even-Toed Hoofed Animals. It is impossible here to describe them separately.

When you some day visit the New York Zoölogical Park, do not fail to inspect the National Collection of Heads and Horns. There alone in all the world, you can find in the Zoölogical Hall fine heads and horns of nearly all the known species of hoofed and horned animals of the world, displayed in Family groups. That Hall will give you a knowledge of the finest "game animals" of the world such as you can find nowhere else in one view.

There will be found in every large zoölogical park or "garden" two buildings for housing two collections of commanding interest. They are the Zebra House, and the Elephant House, for the odd-toed animals of the Class Mammalia.

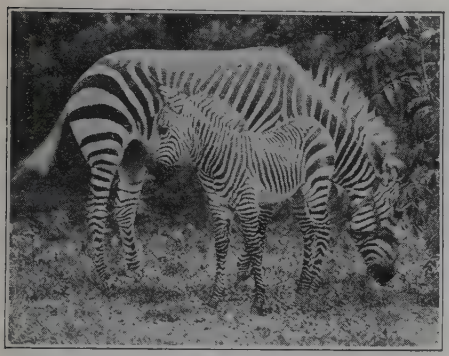
The zebras and wild horses, now confined to Africa and Asia, form collectively two picturesque and interesting groups. Africa owns all the zebras, from the large, big-eared and narrow-striped Grevy zebra of northeastern Africa to the small and broad-striped mountain zebra of the mountains of Cape Colony—of which fewer than 500 head remain alive.

Between the above are three or four other species—Grant's, Chapman's and Burchell's, all very showy and admirable. In Abyssinia, the Egyptian Sudan, Persia and Tibet are found four well-defined species of wild asses: the Somali, Abyssinian, the onager and the kiang. In captivity all these live happily and long; they rear their young to maturity, and always the gorgeous markings of the zebras compel instant attention.

The Prejevalsky wild horse, inhabiting the Gobi Desert of south central Asia, is the species that shows how the wild equine group of Asia is related to the domestic horses of northern Asia.

A large and fully-equipped Elephant House should contain one of the great, big-eared African elephants, at least nine feet high, from northeastern Africa; a specimen of the very inter-

esting pygmy elephant (six feet high) from Liberia, and an Indian elephant, eight feet high, preferably a quiet female instead of a troublesome old male.



ZEBRAS
A mother and her colt.

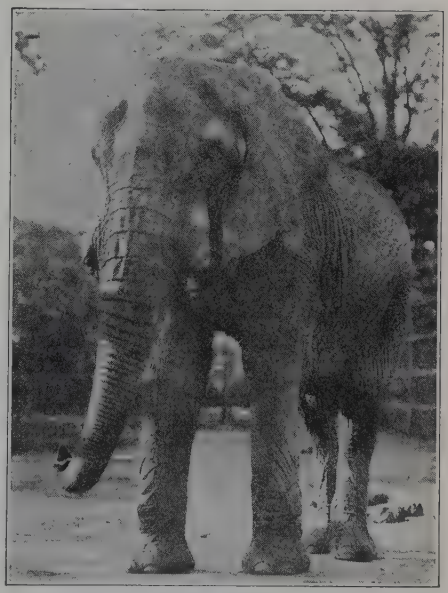
The huge Nile hippopotamus species should have a representative, but one good one is enough. The wonderful, and as yet little-known, pygmy hippopotamus from Liberia—one-fourteenth the size of the full grown Nile hippopotamus—is so very small that a whole family of five can be accommodated. An African rhinoceros is absolutely necessary; but the Great Indian rhinoceros from Nepal is so rare, and so costly ($8,000), that it certainly is a luxury not to be found in every zoo.

Finally, the queer Tapir Family should be represented by three species: the giant Baird tapir from Central America and Panama, the common South American tapir, and the big black and white Malay tapir, of the Malay Archipelago and southeastern Asia.

No zoo is complete without a good collection of those most strange of all pouched animals (Marsupials)—the kangaroos and wallabies of Australia, the wombat and the Tasmanian devil. At birth the young of a large species of kangaroo is about as large as one inch of a lead pencil. That weak, hairless, almost helpless lump of kangaroo flesh is born with just strength enough to enable it to scramble into its mother's pouch, attach its mouth to the source of nourishment, and there remain for two months. A baby kangaroo maintains its claim on its mother's pouch for three or four months.

Birds at the Zoo

No visitors enjoy zoölogical parks more than do the lovers of birds. Taken one by one, the birds are rather more perfect as exhibits than the mammals. They are always visible, they pose naturally, they do not run away, and only a few of them bite or strike dangerously.



KHARTOUM
Great African elephant which measured 10 feet 8½ inches in height and weighed 10,390 pounds at the time of his death in 1931.

What can possibly be more cheering, or more restful to tired nerves, than a great roomful of beautiful birds busily feeding, drinking or flitting to and fro, and singing or squawking to show their joy in life? When weary or depressed in spirit, there is no better

place to go than into a birdhouse full of tropical birds, to let their happiness and care-free spirit restore our own cheerfulness.

A large house for tropical birds becomes a houseful of feathered treasures. As you behold scores of ample cages, each one occupied by a rare and beautiful bird or flock from some far distant place, you feel like a miser awakening in a chamber of jewels. And what else than jewels are we to call the king bird of paradise, the greater bird of paradise, the bright orange cock of the rock, the marvelously groomed touraco, the satin bower bird who builds a wonderful playhouse, the toco toucan, the sun bittern—and fifty others that we could name?

When weary of mere beauty of form, color and plumage, turn to the bizarre rhinoceros hornbill, the concave-beaked hornbill, the road-runner, the crown pigeons and the ever-flitting blue mountain jays. Then notice the collection of native warblers, thrushes and other songsters, and the calm and serene collection of pigeons and doves. The strange bleeding-heart pigeon sometimes prompts a sympathetic visitor to hunt up a birdkeeper and report that "A pigeon has been stabbed in the breast, and is bleeding."

The collection of macaws, parrots, parakeets and lories at the New York Zoölogical Park is of commanding size. It contains nearly 100 species. The small lories and parakeets in small cages are so kept because we have found that they are happier and live longer than when they are in large cages, where they are afraid, and do not seem to know what to do with themselves. The first rule laid down in designing a birdhouse should be that as many as possible of the cages should be large and high, and contain community groups of as many birds as will live together in world peace.

This brings us to the crowning feature of the Large Bird House, the central flying cage, wherein many species live together in a happy family, as if the same mother had brooded them all. There are a few ducks, numerous shore birds, a few quail and many perching birds. Into that paradise of birds, no quarrelsome newcomer may set foot or spread a wing.

But there is another and far more imposing happy family of birds. It will

PYGMY HIPPOS

These animals are from Liberia. One of these was born in the New York Zoölogical Park.

RED KANGAROO
No zoo is complete without this strangest of all pouched animals.

POLAR BEAR
This is not in Greenland, but in the zoo. On account of their pursuit by fur traders, live polar bears are becoming scarce and high in price.

be found in the huge but light-looking Flying Cage, containing several living trees, and a swimming pool a hundred feet long. In that spacious interior, gulls, herons, brown pelicans and cormorants nest; and the gulls take long flights. The birds delight in swimming, diving and playing in the pool and make a pleasing spectacle for the visitors. This is a most excellent place in which to study the water and marsh birds of North America—ducks, cormorants, white and brown pelicans, swans, gulls, terns, gallinules, coots; herons, egrets and ibises.

KING PENGUINS

These are the largest of the penguins and stand about three feet high. The penguins are short-legged, flightless birds which stand erect but walk clumsily.

Adjoining the Flying Cage appears the cranes' paddock—a little park of green grass, beautiful trees, and a running brook. Here a surprisingly large number of cranes from many distant lands live in peace and harmony. The rarest and most valuable bird is the great white whooping crane of North America, of which probably not more than one hundred specimens now remain alive. In all North America there are not more than three or four of these birds in captivity. The quarrelsome saras crane of India is not here. Africa contributes the crowned and the demoiselle, Japan her large white-necked species and North America adds the vanishing sandhill and the little brown crane.

Of the waterfowl of the world, the geese form the most satisfactory exhibits—after the swans and pelicans. The best display of Canada geese is to be found roaming free and unrestrained—flying, returning, resting and feeding at will. The main park flock contains about forty birds with perfect wings, and several times each day they take wing, rise high in the air, circle and honk round and round at an elevation of five hundred or a thousand feet, and finally glide down at the eastern end of Cope Lake, and settle upon the precise patch of lawn which they have made wholly their own.

In the goose paddock near by are to be found in summer fine specimens of geese, gannets, frigate birds, murres, and at intervals penguins. Once only has one of its yards contained albatrosses. They are hard to get, and hard to keep. Formerly, a group of King penguins from the South Georgia Islands were kept at the pool near the Reptile House.

Meandering southward up Birds' Valley the eagles, condors and vultures soon are found. Until seeing them there, we did not realize that the world contains so many vultures, great and small, as that collection reveals. Of the really big ones, the American continent contains only two, the California condor, now rare, and the great condor of the Andes. The king vulture of South America is the only really beautiful vulture. All the other big vultures

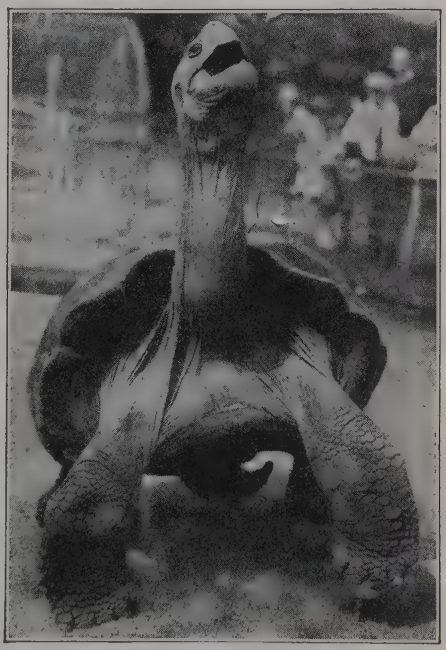
belong to Africa and Asia. About them we feel no great enthusiasm. The United States national white-headed and white-tailed eagle (the bald eagle) is much more to our liking. There are several eagles that are beautiful, notably the harpy of South America, and the bataleur of Africa.

Of the upland game birds the pheasants of the Old World make the only successful and really satisfactory exhibits in a zoo. The grouse do not live long. The quail species do better but their exhibition value is limited. The pheasants of the Old World, however, are of many kinds. Some of them are amazingly beautiful, and some are remarkable in form. The standardized zoölogical park must have a good collection of species, including the golden, silver, Lady Amherst, Reeves', Impeyan, argus, fireback, ringneck, and the Javan peacock. In a perfect pheasant aviary these birds are given the following choices; sunlight, shade, sand, concrete, open shelter or closed shelter. In a collection of pheasants, all is not just as the visitor would have it. During the heavy visiting hours, many of these birds retire to their inner compartments, where they cannot be seen. This disappoints many a visitor, but it is not good to force birds to stay in the open when they have private reasons for wishing to retire.

Finally, the Ostrich House contains one of the most interesting of the bird collections. There are the two species of big and burly African ostriches, which have some heat in their quarters, but the birds are free to go in and out all winter. The curious cassowary and the odd rhea are here. The male rhea sits on the family eggs while they are incubating, and attends to them with constant care. In general habits this South America bird is similar to the African ostrich and is sometimes referred to as the American ostrich.

THE REPTILE HOUSE

The first gift of the New York Zoölogical Society to the people of New York was the Zoölogical Park's wonderful Reptile House, and a really great collection of living reptiles. That choice was made because the millions of New York's people knew something of certain other animals, but almost



GIANT TORTOISE

The tortoise is a land turtle. This giant specimen is from the Galapagos Islands. Turn to Page 213 for a picture of a turtle.

nothing of the Class Reptilia, and its four Orders of Serpents, Lizards, Crocodiles, and Turtles. For twenty-five years the millions of visitors who annually come to the Park have been seeking answers to the eternal question—what are the poisonous snakes, and what do they look like? Along with a very dangerous, and even terrifying series of rattlesnakes, copperheads, cobras of six or seven species, vipers, fer-de-lances and bushmasters, the Zoölogical Park has been diligently instructing the people of the United

States regarding the anti-venomous serums for snake bites, where to get them and how to apply them. Anti-venomous serums for snakebite are made at Sao Paulo, in Brazil, by Dr. Vital Brazil, the famous specialist on snake poisons, and more recently by the Anti-Venin Institute of America at Glenolden, Pa. If the serum can be applied within a day or two, it may fairly be regarded as a sure life-saver.

No, it is not necessary to feed snakes on live animals. We quickly kill the animals, offer them when warm and relaxed, and the snakes readily accept them. Ethically, it is not worse to kill them for snakes than for the market.

In this Reptile House there is a large series of live snakes so placed that every visitor can see their forms and colors at a distance of only two feet, or even less; which promotes the ability to distinguish between species. Every poisonous species is marked.

The labels of the Zoölogical Park convey much descriptive information for the benefit of the serious-minded student who seeks useful knowledge of the wild creatures of the world in this great collection of animals.

GREAT ANTEATER

This interesting animal from South America is entertaining visitors at the zoo. When first caught, the anteater is peevish for a time but quickly settles down.

*All illustrations, except one on Page 259, by courtesy New York Zoölogical Society; Elwin R. Sanborn, photographer.

Book *of* the Races

In Asia
In Australia
In Africa
In the Americas
In Europe
In the Island World
Table of Races

Courtesy Field Museum of Natural History

A PATAGONIAN

This man is from the southern part of South America. This type of Indian is noted for tallness.

DAUGHTERS OF SWEDEN

BOOK OF THE RACES

WE are going to look over the whole world and see something of the different kinds of men and women who live in it. There are really great differences between the peoples of different districts. We shall find tall peoples like the Indians of Patagonia, and little peoples like the Pygmies of central Africa and the Negritos of the Philippines. We shall find peoples with fair skin and light hair and blue eyes, like the Swedes; but we shall find many more peoples who have dark eyes and black hair.

ONE RACE OR MANY

There has been much discussion and disagreement as to whether the different kinds of man have come from a single stock and were once all alike, or whether they have been different from the beginning. Even today there is no certain answer to the question. Most students believe that the different races of mankind are closely related to each other, and form but a single species, and that the different races have grown up out of an original similar mass of population. Students who believe this are known as monogenists. A number of excellent writers, on the other hand, believe that mankind has existed from the beginning in different types.

At all events, today we find men presenting a number of well marked and different types. When we ask how many races there are, we again meet with disagreement. Huxley claimed that there were two; many French writers recognize three; when I was a boy in school, we learned that there were five—Caucasian*, Mongolian, Malay, American Indian, Ethio-

*The term Caucasian may be used in two ways—(a) as the general name for a great race, which is called "white," and includes many widely different types, some of which are far from white; (b) for the distinctly white, though both fair and dark, peoples of Europe. Clearness will be gained by using the term Caucasic for those people of the Caucasian race who vary in one way or another from the European types.

pian; many recent writers, like Keane and Brinton, recognize four. They would recognize as distinct races, all of the five mentioned, except the Malay, which they consider a branch of the Mongolian; there are, however, writers who recognize as many as thirty or forty races of men.

It is not a matter of very great importance to us whether we are monogenists, or how many races we recognize. There are, of course, many more than five markedly different *types* of men. Within each of the great races there is variation. If we recognize four races, one of which is the American Indian, there would be the least variation and difference found in that race; the greatest variation would be in the Caucasian race. There is much more difference between the fair Swede and the dark Italian, the Ainu, the Polynesian, and the Basque, than between the Patagonian, the Aztec, the Iroquois and the Pueblo.

What makes a race type

There are hundreds, or even thousands, of peoples, each with its own geographical location, language or dialect, mode of life and physical type. What do we mean by a racial—or physical—type? These types are based upon physical characters. When we speak of a race type, we mean a group of people who have a certain combination of characters, which marks them off from other peoples who present characters differently combined. The characters which are usually used in defining race types are stature, color, hair, nose and head form.

The differences between races and nations

We must be careful not to confuse the idea of nation and of race. A nation is a political group which may be made up of a single race, but is much more commonly composed of individuals of different races. Thus Germany is a nation, which is composed of people presenting very different race types. There are parts of Germany where a tall blonde type prevails; there are other parts where the people are much shorter, of different build, and brunette in color. In the same way, in Great Britain we have not one race type, but a confusion of many. Here in the United States we have American Indians, millions of negroes, and a mass of white population that is composed of a mixture of a great variety of Caucasian race types. We are here studying peoples and tribes, rather than nations. We are interested in the different types of mankind.

If we believe that mankind is of a single stock, the different race types have been formed from the early single type by migration and life in new places. In other words, we believe that they are the result of the surroundings in which they live. We cannot tell just what it is in the surroundings which makes new types; we do not know exactly how the environment has worked to produce the types; we are not sure that these types have been always produced by sharp and marked differences. If we are monogenists, however, we say that the different types have in some way been produced by their surroundings, and the facts of distribution seem to agree with that idea; we find each of the great continents has a type characteristic of it. Thus the continent of Asia is the home of the Mongolian, or yellow race; Europe and northern Africa—which are really one continent—are the home of the Caucasian, or white race; Africa is the continent of negroes, the Ethiopian, or black race; North and South America are the home of the American Indian. It

would be, however, a mistake to think that each continent has absolutely no population excepting the type which marks it. Thus, in Asia there are some tribes and peoples of Caucasic type; not all the native peoples of Europe are certainly Caucasian; and Northern Africa is not truly Ethiopian.

Mingling of the Races

The last two hundred years have been a period of great and rapid change over the entire world. Restless European traders have traveled far and wide, carrying new ideas and new practices with them. It is difficult to find any section of the world to which they have not gone, or any people so separated and far away as not to have been influenced by them. Old customs have passed away. Old languages have partly or wholly disappeared. Blood has mixed, and it is difficult to find a tribe or people who present a pure and unmixed type. We shall find, then, signs of this change everywhere. We are trying, however, to find the races and race types such as they were a little time ago. We are studying the life and customs of a period that is ending. The trend today is toward a greater uniformity of life, everywhere.

Just as the racial type is believed to have depended on the surroundings and to have been produced by it, the mode of life or culture has been the result of the environment. For culture this is certainly true, whether man is of one or of different stocks. Every culture is the result of the surroundings. You may have already, in these books, read the story of the Eskimos, the Filipinos, the black peoples of Africa, the peoples of the desert. If you have read these stories carefully, you see that the life and culture of these different peoples is beautifully adjusted to their surroundings. If we should examine the life of the American Indians, we would find this truth perfectly shown. The Indians of different regions are different in habits and customs. The life of the Iroquois in their eastern woodlands, of the Sioux of the plains, of the Pueblos of the desert and of the fishermen of the Northwest Coast, each is different from the other, plainly due to the differences in surroundings.

How Different Peoples Are Adapted to Their Locations

To many people the customs and habits of other peoples seem "strange." We must always remember that what

Courtesy Lingnan University
CHINESE GRINDING RICE

seems strange to us because it is different from what we ourselves do is not really strange. Every people, in every district, has learned how to live. The way they do things is natural, considering their surroundings. The black man in Africa does many things differently from us; his way, however, is very good for his surroundings. He would find our ways as strange as we find his. It is often said that the Chinese and Japanese do almost everything opposite to ourselves. It is not true, but they do many things quite

opposite to us. Thus, they write in columns from above downward, and these columns are read from right to left. We write in horizontal lines from left to right. To us this seems strange. There is, however, no advantage in writing in horizontal lines from left to right. The Chinese and Japanese way is just as good as our own. Our compass points to the north; the compass of the Chinese points to the south. A compass that points to the south is just as good as a compass that points to the north, and, after all, it was the Chinese who invented the compass. When we eat we use a knife and fork; Chinese and Japanese eat with chopsticks. There is nothing funny about it, and it is much more refined than our own method. They let the butcher and the servant tear meat to pieces before their meal is served, instead of playing the part of servant and butcher after food is set before them. In our study we shall, of course, find many things different from our own. We must not think that they are necessarily inferior.

Nor have we any right to talk too much about what is superior or inferior. If human races are different from the beginning, there is no more question of superior and inferior than there is between different kinds of animals. Who shall say that an elephant is superior to a rhinoceros or a hippopotamus? It is different. These animals lead a different life. Each is adapted to its own life and no other. If it could think as we do, no doubt a hippopotamus would claim that it was superior to an elephant, or a rhinoceros. If the different race types came from a single ancient type, the differences are, as we have already claimed, due to groups living in new surroundings. If so, it must be that each type is well adapted to the district in which it is found. It is probably better suited to it than any other type. The black man of western Africa is better suited to life in western Africa than is the white trader with whom he comes in contact. In the same way, the American Indian was better adapted for life in the American Continent, as it was at the time of the Columbian discovery, than the white men coming from Europe were. Every human type thinks itself superior and judges others by itself. In our examination of human types and customs, we should try to rid ourselves of this tendency to judge and criticize, and to realize that different cultures and different race types may be equally good and admirable.

In Asia

We can, of course, describe only a few of the different peoples of the world. We shall begin with that greatest of all continents, Asia. It was probably man's first home. In saying that it is man's original home, we do not necessarily mean that the precise spot where mankind first appeared still exists or forms a part of Asia. Many writers believe that man first appeared in the extreme south of Asia, and that the very spot has disappeared under the Indian Ocean.

We have already stated that today Asia is the continent of the great yellow race—the Mongolian. The race type is seen perhaps in its best form in the great plains of the North. In Siberia are many Tatar tribes. We think of them as peoples of medium stature, with broad, flat faces; with broad, short heads; with a brown color that has a distinct yellow tinge. The flat, broad faces have rather small features and black eyes which shine like beads, but, to us, seem to lack expression. The Mongolian type is marked by coarse black hair, which hangs straight and lank, with no tend-

ency to curliness or waviness. These peoples are largely nomads or rovers. They are great horsemen and have herds of reindeer, which supply them with food and many of the necessities of life. They live in low tents, with rounded tops, which are made of hair beaten together into a kind of felt. Interesting studies have lately been made of many of these tribes by Russian students; and it would be interesting, if we had time, to tell you much about them.

Among other yellow peoples, certainly related anciently to these Northern Tatars, are the Koreans and Japanese. Although both unquestionably started from Tatar ancestry, they differ today greatly from each other. The Korean is much larger than the Japanese; he is much slower in gait; when he walks it is with a long and stately stride, quite unlike the short-stepped, pattering gait of the Japanese. In their life we find great differences. Both have been much affected by the Chinese, and yet even in their borrowed customs they differ from each other. Both eat with chopsticks—a Chinese invention—but the Koreans eat much meat and little fish, while the Japanese eat little meat and much fish. The dishes of the Koreans are mainly made of brass and their chopsticks and spoons are brass; the dishes of the Japanese are chiefly porcelain, or earthenware, and their chopsticks are of wood. The dress of the two peoples is totally different. The Koreans wear the dress of China of five hundred years ago, while the Japanese costume is unlike any other. It would be easy to point out many other things different in their daily life.

Courtesy Japan Magazine

JAPANESE WEARING COSTUMES OF THE PRESENT DAY

When we speak of Mongolians we always think first of the Chinese. They are the most important in number and area, of all the Mongolian peoples. If there are differences between the Koreans and the Japanese, both of whom are unquestionably descended from Northern Tatars, the differences between Japanese and Chinese will be found to be still greater. We commonly speak of Chinese and Japanese together, and many people seem to

Courtesy Field Museum of Natural History

BURMESE CHILDREN

This interesting group displays black hair and brilliant black eyes.

think they are the same. It would take a large book to state the differences. There can be no question that the Chinese came from the West, but exactly where they came from is uncertain. They brought with them a culture already well developed. They were not the first dwellers in China, but found many tribes there, differing from each other and from themselves, in physical type, in language and in customs. Some of these tribes were destroyed, but of others fragments still remain in the population of China today. The Chinese were a civilized people thousands of years ago. At that time both Koreans and Japanese were living in a much lower state of culture. The whole of eastern Asia has been greatly influenced by the Chinese, who have been teachers and leaders. Some of the greatest thinkers the world has ever known lived in China many centuries ago. Laotze and his followers have perhaps never been surpassed as philosophical thinkers. Confucius is no doubt the greatest teacher of all time, whether we consider the number of people who have been affected by his teachings, or the period of time through which his teachings have endured. It happens, curiously, that these two great men lived at the same time—about five hundred years before the time of Christ; it was really one of the most brilliant moments in human history. In China, Laotze and Confucius; in India, the Buddha; and in Greece, Socrates and Plato, lived at about the same time. It is probable that no other moment in human history has shown such a flowering of lofty thought. The Chinese, thousands of years ago, were diligent cultivators of the soil; they wove fabrics of great beauty, including silk; they knew the use of metals and especially were notable workers in bronze; they had carried the arts of pottery to a perfection known nowhere else; they had perfected a remarkable system of music; they had devised an excellent form of government; they had invented writing and made books. At that time no population of Europe could compare

with them in culture, and the peoples living in what today is Great Britain, France and Germany, were far behind.

Besides the nomadic or roving peoples of the north, the Koreans and Japanese, and the Chinese, there are many other Mongolic tribes and peoples in Asia. In southeastern Asia, we find the Siamese, Burmese and others. And in Tibet, the bulk of the population is of the yellow race. All these peoples, while presenting interesting differences, were influenced by China. We have no time to point out the features of their daily life. Nor have we time nor space to speak further of the great Mongolian race proper. We shall, indeed, later on say something of the Malays and the American Indians, who are by many considered branches of this great Asiatic race.

We must, however, say a few words about Caucasic peoples in Asia. You may read, in another of these volumes, about the Ainu in Japan. Their origin is a difficult problem. They are not Japanese nor related to the Japanese. They once occupied the whole of what is now Japan. When the Japanese entered their islands from the mainland, coming down apparently through the Peninsula of Korea, they came into conflict with the Ainu, just as European settlers came into conflict with the Indians in our continent. Just as our pioneers gradually dislodged the Indians and drove them westward, just so the Japanese crowded on the Ainu and drove them northward. The Ainu present a true Caucasic type. They are of medium stature; their faces are not flat and broad like those of the Japanese, but the nose is prominent; the features rather large; their skin is white; their hair wavy and sometimes brown instead of black; the hair upon the face and body is so thick and abundant that the Ainu are often called "the hairy Ainu." In all these respects, the Ainu differ greatly from the Japanese and show Caucasic traits. Among the native populations of China which have not yet wholly disappeared, are the Miaotze. The name itself means "hairy people." The Chinese, like the Jap-

Courtesy Field Museum of Natural History

HAIRY AINU

A true Caucasic type. Formerly the Ainu occupied all of what is now Japan.

SINGHALESE

Caucasic type from the British Island of Ceylon, off the southeastern coast of India.

anese, have very little beard and body hair; the Miaotze, like the Ainu, have abundance of both. Whether there is a relation between the Miaotze and the Ainu, is uncertain, but is not impossible. In the southwestern province of China, Szechuan, dwell the Lolos. The Chinese speak of two kinds of Lolos—the conquered and the independent. The conquered Lolos live in the lower lands and recognize the control of the Chinese. The greater part, however, of the Lolos live in high plateaus and rugged mountain

MAORI CHIEF
Native type from New Zealand.

districts. They have bidden defiance to the Chinese for many centuries; and even today, while their country is included in what is known as China, the mountain Lolos recognize no control. They are very little known. Few travelers have ever penetrated into their mountain fastnesses. A few years ago the Frenchman, d'Ollone, made an expedition across their territory. Everyone who knows them speaks of the Lolos as being distinctly non-Mongolian, and all claim that they present notable Caucasic features.

India is almost a continent in itself. The hundreds of millions of people who inhabit it make a difficult study. There are scores of different peoples, each with its own language, territory, customs and tribal government. Some of these are clearly Mongolian; others are as clearly Caucasian; some seem to be neither one nor the other. One of the most curious hill peoples of India are the Todas. Here we have a people who, in their features —wavy hair, abundant beard and body hair—remind us of the Ainu and must perhaps be considered Caucasic. We have no time in which to speak of their most interesting customs. They are raisers of cattle and users of milk; their life and customs center about the cow, which with them is sacred and connected with curious ceremonies. In India, as in China, we find one of the oldest civilizations of the world.

Is there a relation between language and race

It is customary for students of races to give much weight to language. When we find two peoples speaking the same or related languages, it is natural to think of them as related in blood. It is not always true, however. For example, here in the United States there are millions of blacks, descendants of Africans, who have no language of their own, but who speak English. It would clearly be a mistake to think of them as near relatives of the English speaking whites, because of their use of the same language. In the same way, in the countries of America, lying south of us, millions of people speak Spanish, but are not Spanish in blood, being Indians of the great American race. It is possible for a population to lose its original language and to gain a new one. Is it possible for a

people to retain an old language and to gain a new physical type? Such a question arises in regard to a number of peoples, like the Turks, the Finns, the Hungarians and the Bulgars. These peoples do not at all present the true Mongolian type; yet they speak languages that are clearly related to those of the Tatars of Northern Asia, the Japanese and the Koreans. Are we to consider that these peoples were yellow, or Mongolian peoples, who moved west from Asia, and who lost their physical type while retaining their Tatar languages? We shall not attempt to solve the problem, which is a difficult one.

While the Todas are one of the hill tribes of India and are clearly Caucasic, not all the hill tribes are such. Many of them speak languages that are so closely related to each other that they have been grouped into one family, and came, probably, from a single parent language. The name Dravidian is given to this language family and to the tribes that use it. They present some peculiar features, and how they should be classed among the races has been a matter of discussion. They are people of fair stature, of brown color, of hair that is neither straight nor curly. Some writers have even suggested that the Dravidians should form a race apart, and that with them the Australian tribes should be connected. It is true that there are some similarities in culture—for instance, the throwing stick, or boomerang, occurs among some Dravidian peoples, as well as in Australia.

In Australia

Commonly, the natives of Australia are reckoned with the black peoples. In fact, they strongly resemble some of the negro populations in color and in features, although they have not the woolly hair of true negroes. There were originally many tribes of Australian natives, all of which presented a characteristic curious culture. It was marked by many features that are not actually found elsewhere. Agriculture was in an exceedingly low stage of development. The island-continent had a fauna and flora of its own. Animal life was less common and abundant than in many other places, but hunting was the chief resource of the natives. The habits and customs of Australian tribes have been seriously studied by many English writers, and their curious marriage customs have been described repeatedly.

Not far from Australia lies Tasmania, or Van Dieman's Land. The natives of this island were of a particular type related to the Australian, but presenting some features of difference. The Tasmanian was a shorter, stockier man, and his black hair was more pronouncedly curly, while his features were more distinctly those of the negro. The culture of the Tasmanian was one of the lowest known. The Tasmanian type is perhaps the only well marked racial type that has become actually extinct within historic times. The last of the Tasmanians died about 1865. The people were a gentle, inoffensive population, which was treated with extraordinary cruelty by the incoming white population, and was practically hunted to its death.

In Africa

We turn now to the second continent in point of size—Africa. From the point of view of zoology, botany and human population, it is divided into two parts. The portion of Africa lying north of the great desert in climate, animal life, plants and human population, belongs with Europe. The portion of the continent south of the great desert, forms a vast area sharply

characterized by its physical and life features. Years ago, in his little book on the races of man, Dr. Brinton suggested that the northern part of the great continent should be connected with Europe under the name of Eurafrica, while the southern area should be called Austafrica. His suggestion has not been accepted, but it indicates a difference which must be recognized.

We find that the population of Africa, south of the great desert, represents the great Ethiopian, or Negro, race type. We find that it must be divided into several subdivisions. It is common to recognize three, if not four, groups of dark Africans—the true negroes, Bantu, Pygmies and Bushmen.

The Bantu are the most numerous of these. Until the white man pushed his way into Africa from Europe, Bantu peoples occupied fully two-thirds of Austafrica. It is a mistake to use the word black in regard to African negro peoples. It is rare that one may see even an individual who deserves the name. The Bantu generally are a chocolate brown. They are of medium or tall stature; they have crisp black, woolly hair; the lips are somewhat thick; the nose broad and low; the head shape varies, but is rather long and narrow, as a rule. While the body is well developed and the muscles full and strong, yet the body is rather slight and the hands and feet delicate and small. The Bantu peoples are quick and intelligent, especially in early life; children are extremely quick in grasping new ideas. There are scores, perhaps hundreds, of Bantu tribes, each of which has its own territory, language, customs and tribal government. The languages, however, are as much alike as French, Spanish, Portuguese and Italian, and they all clearly have come from a single, ancient Bantu language. Each of the Bantu peoples has its own tribal name. It would be tiresome to list them, but as examples we name the Bakongo, Bakuba, Zulu and Swaheli. The northern Bantu occupying the distinctly equatorial portion of the continent, are farmers and live for the most part on the produce of their fields. Some of the southern Bantu tribes raise domestic animals—especially cattle and goats—on a large scale. These tribes count their wealth in cattle, and make great use of milk and hides. The agriculture of the Bantu peoples is what is known as hoe-culture. There is no use of elaborate implements for tilling the soil, and in most districts there are no animal helps for farming. Agriculture is the business of the women.

It is in this region that we find, perhaps, the largest development of polygamy and slavery. It is not uncommon for chiefs to have considerable numbers of wives, or slave women. When I was living at my own headquarters in the heart of the Congo Free State (now Belgian Congo), the nearest chief—a Baluba—had fourteen wives; the nearest chief on the other side of me, Ndombe—a Bakuba—had more than thirty; in other parts of the Congo Free State, I met chiefs who had sixty, a hundred, and at one time one was pointed out to me as having six hundred wives. When it is said of an African chief that he has sixty wives, both wives and female slaves are included in the statement. There is little difference between them. Throughout the whole of Austafrica marriage is a matter of buying a woman. The man who wishes a wife bargains with the father or brother of the woman whom he wishes and a price is finally agreed upon. When it is paid, the woman becomes the wife of her purchaser. The first wife to be bought has an advantage over

other women owned by her husband later. Even though some of his new purchases may be more beautiful and more attractive to him, the first wife is entitled to a special degree of consideration and respect. If the woman is not satisfied with her husband, if he is unkind or brutal in his treatment of her, she may appeal to her relatives to be taken home. In such a case the price which he paid for her is returned and she is free to be married or sold to another man. A slave woman differs from a wife in that she is bought from an owner who is not related to her, instead of from her father or brothers. Such a woman has no place of refuge in case of bad treatment by the man who buys her. He is, however, prevented from treating her with much cruelty, as she may run away to another village and beg the chief to buy her from her former owner. People who hear of the polygamy of Africa, often assume that there is much jealousy and hatred between the wives and slaves of a great chief. There may be some such feeling, but on the whole it is not great, nor noticeable. The many wives of a Bantu or negro chief usually get on fairly well together. When quarrels do occur it is usually over children. Every chief who has a number of wives has his own house, in which he receives visits from his friends and conducts affairs of business. Each of his wives or slave women has her own house, and her children live in the house with her. Each wife or slave has her own field in which she works. The work of the women, besides field labor, includes the care of the fire; the preparation of food; the making of basketry, matting, pottery and so forth, and to some degree, the weaving of native cloths.

It may be asked what work remains for the man in Africa. He is, of course, the hunter, but hunting is usually a matter of no great importance; he does some of the fishing, but in many Bantu tribes the woman also fishes. He is the fighter and protector of the village. He is also the speaker and religious leader. He makes his own weapons, does the higher class of weaving, and if embroidery is practiced as a decoration of clothing, he may be the user of the needle. The different tribes of Bantu have characteristic house architecture and village arrangement. In fact, it may almost be said

Courtesy Field Museum of Natural History

PYGMY

The type that is common in the Belgian Congo.

that every tribe differs in detail from every other tribe in its house construction and arrangement. If you had not been told elsewhere (Vol. V.) the story of the African natives, I should go into much detail regarding the life of the Bantu peoples and should particularly emphasize the differences between those who depend purely upon tilling the soil and those who pay considerable attention to cattle raising.

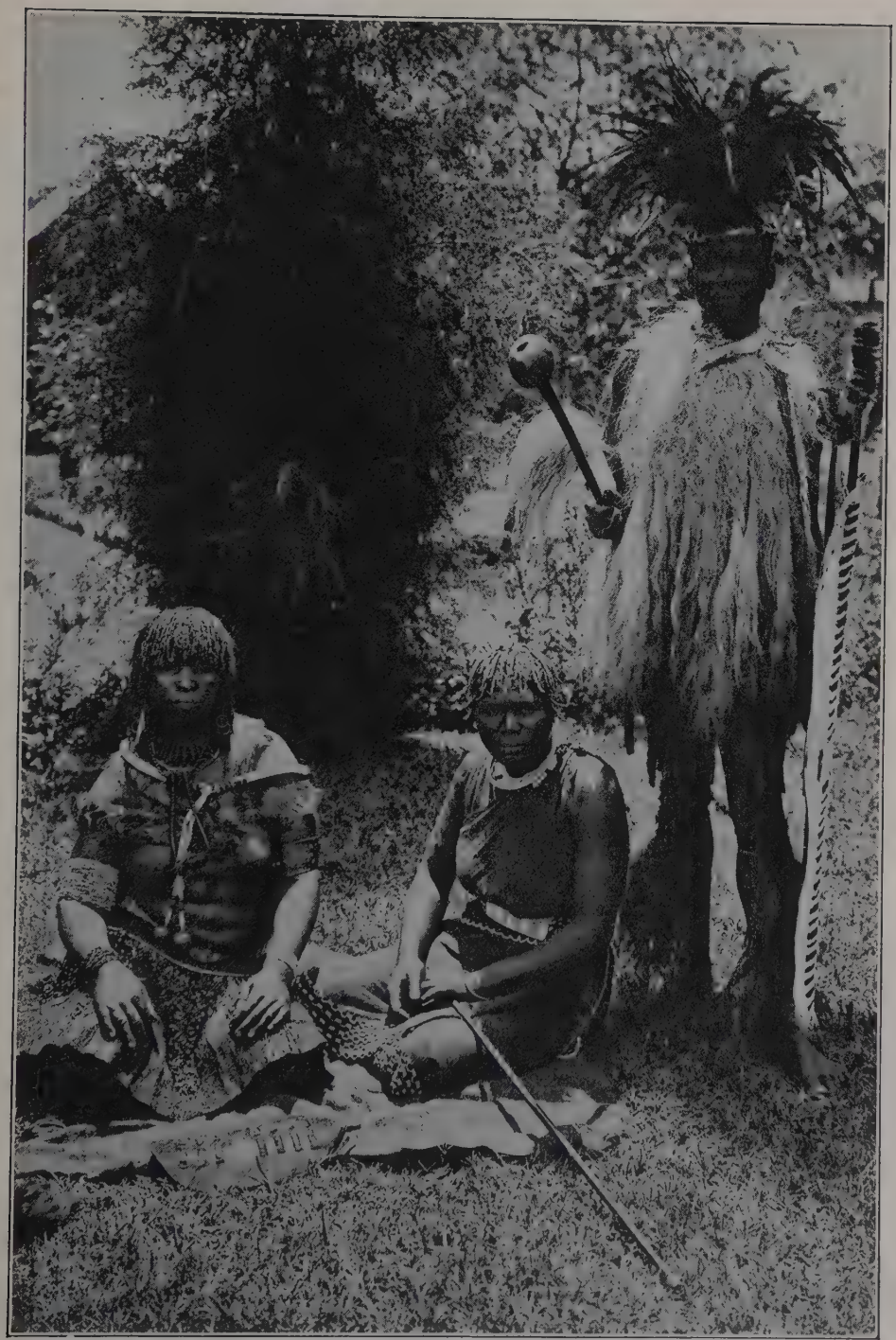
We have already said that the whole of southern Africa, from the Equator

to the Cape of Good Hope, was occupied by Bantu peoples. North of their area we find the true negroes. They occupy a belt lying south of the desert and stretching across the entire continent from west to east. The Sudan, Sierra Leone, Liberia, French Guinea—these are areas of the true negro populations. On the whole, the true negroes are taller, heavier, more strongly built, than the Bantu. They are nearer to true blackness, and in their dark brown color there is a dis-

Courtesy American Museum of Natural History
AFRICAN BUSHMAN
A representative of the big blacks of the Kalahari Desert.

tinct blue or purple tint that is quite characteristic; their faces are larger, their features heavier, their lips thicker, their noses broader and flatter, than the Bantu; their heads are much narrower in proportion to their length. Mentally the true negroes are perhaps less quick, they are certainly less worldly-wise than the Bantu peoples. The general life picture is much the same. They are farmers and have many wives and slaves. They are quick in their emotions, but on the whole kindly and good natured.

In addition to the true negroes and the Bantu, we find two very interesting populations in Austafrica—Pygmies and Bushmen. The Pygmies never live together in large numbers, nor occupy continuous areas of any size. They live in little groups of from ten or twelve to forty or fifty persons. They are for the most part forest dwellers, but their little villages are generally close to villages of big blacks. Their houses are almost everywhere of much the same construction. They consist of a light framework of branches built into a hemispherical form. This framework is covered with a thick sheeting of large leaves, which are tightly bound down upon the framework by means of vines. The Pygmies are little people. Adult males average less than five feet in stature. The females, of course—as in practically all human population—are smaller than the males. The Pygmies have almost no agriculture, but are good hunters. They use spears and bows with arrows in their hunting. Their arrows are often poisoned. The Pygmies are dark in color, but often have a suggestion of yellow in their tint; their hair is woolly; their features are much like those of the big negroes, but they have a curious, cunning and suspicious glance which is quite characteristic. We have already said that they build their little villages, the houses of which are usually arranged in a great circle, at the edge of a village of big blacks. This is very curious. There is no real affection between the two peoples, but there is a relation that may be said to be helpful to both. As the Pygmies do very little in the way of cultivating the soil, they depend for their vegetable food upon their big neighbors. The large blacks hate the forest; they are rarely great hunters; they never go off the trails unless it is necessary to do so. The little blacks have no fear of the forest; they love to hunt wild



ZULUS *Courtesy South African Government Bureau*

These picturesque representatives of the Ethiopian or Negro race are natives from Natal.

game; they collect wax and honey and wild vegetable products in their wanderings. These are all things which the big blacks want, and they are willing to trade against the meat and honey, wax, vines, wild fruits, and other things, the surplus from their fields, cloth from their looms, arrow-points and knives made by their blacksmiths. Not only is this trade between the little people and their big neighbors serviceable to both, but the little blacks in their wanderings are more quick to learn of danger threatening the villages than are the big blacks, and give warning of war parties and slave hunters to their neighbors. Although the little blacks are small and few, they are feared by the Bantu and the true negroes. Their poisoned arrows, their suspicious attitude, their uncanny appearance, and the fact that they are generally considered to know harmful magic, all cause this fear. If, however, they treat their little neighbors badly, the Pygmy village disappears and the little people find some other place to settle. So after all, the two groups manage to get on together.

In the Kalahari Desert of South Africa live little groups of Bushmen. It is probable that they are related to the Pygmies of the forest, but they present some interesting differences in appearance and in life. They are of the same size, or even smaller, than the Pygmies; their skin is less dark, and has a more pronounced yellowish, leathery color; their faces give a strange impression of oldness; their bodies are less well developed than those of the forest dwellers. They are less inclined to live as near neighbors to big black villages. The very nature of the desert in which they live makes their food, their scant clothing and the objects of ornament and use which they make, different in kind and material from those of the true Pygmies. It is believed by many writers that the Bushmen and the forest Pygmies are fragments left from a population of little blacks that once occupied the entire continent. If this idea is correct, the big blacks seem to be relatively newcomers in Africa.

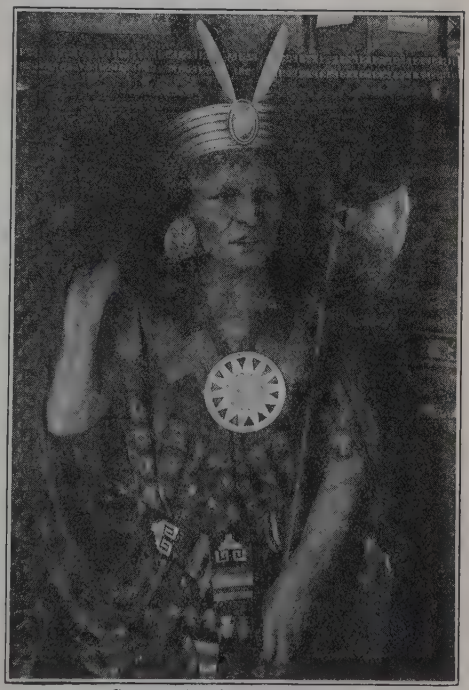
The part of Africa north of the Sahara Desert, and bordering on the Mediterranean, is and long has been an area of Caucasic population. The native peoples of Morocco, Algeria, Tunis and Tripoli are the Berbers. Berbers, Old Libyans and Egyptians are not Ethiopians. It is true that negro slaves have been brought into this area for many centuries and much mixture of blood has taken place. It is true also that trade relations have always existed between Egypt and central Africa, with the result that individuals from the negro belt have constantly streamed into Nubia and Egypt, and from there westward. The actual type, however, of these peoples is clearly Caucasic. The features, the the head shape, the wavy hair, form a combination of features which is not to be gainsaid by any amount of darkness of the skin. And dark skins, of course, are common enough —prevalent indeed—in all this area. The Somali are dark, so dark, often, that it would be hard to find true negroes blacker. But unless he has a mixture of negro blood the features, proportions and head form show that the Somali is Caucasic. Both in the past and present, too, there have been actually fair types found throughout this area. The colored pictures on the walls of Egyptian tombs represent the Old Libyans as blond with fair hair and blue eyes. In the mountain fastnesses of Berber tribes today, the same long-headed, fair type is found. All these tribes of northern Africa speak as their true mother tongue,

languages which show close relations and which form a family known as Hamitic. It is distinctly different from the true negro family of languages and from the Bantu.

In the Americas

Passing now to the great double continent made up of North and South America, we find a type of man singularly uniform. It is true that there are American Indian tribes that are relatively light and others notably dark; there are tribes of great stature —the tallest of all mankind—like the Patagonian and Iroquois—and there are tribes like the Otomi of Mexico, which almost suggest Pygmies; there are tribes with rather long heads, like the Iroquois and Cherokee, and tribes with broad heads, like the Mayas of Yucatan. But after all, the American Indian is so much alike as to attract attention. Some of the old writers said, "When you have seen one American Indian you have seen all," and "The American presents the same type from the cold waters of the North to the cold waters of the South." These are extreme statements, but it is true that less range of types is shown within the limits of the great American race than in any other. When, however, we come to examine their languages and life, we find notable differences. There are hundreds of American Indian languages. We are not speaking here of mere dialects, but of languages actually different from each other.

The general scheme of life is determined by the surroundings in which the different groups have lived. The Iroquois represent the Indians of the eastern woodlands. It is a district of hills and vales, of pretty lakes and pleasant streams, of forests and open glades. The tribes that lived there were admirably adapted to their surroundings. Here we find settled villages; cultivated fields, considerable development in government. The league of the Iroquois, or the Confederacy of the Six Nations, is a remarkable governmental organization. It was in this district that the birch bark canoe was common, and that methods of fishing and hunting, varied and adapted to different forms of game, were well developed.

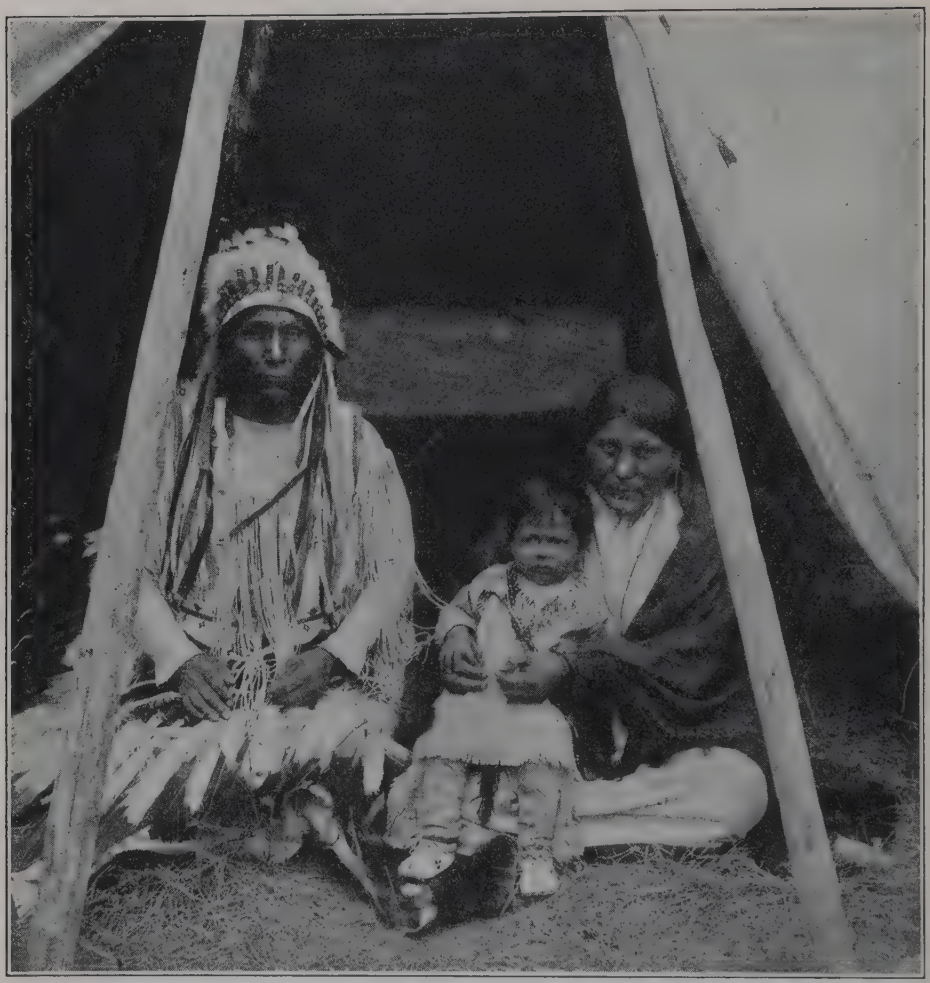


Courtesy American Museum of Natural History

INCA

This bust was modeled after careful study of Inca skulls and native paintings. The Inca culture was one of the highest among the American Indians.

Farther west, on the great open plains where herds of countless buffalos ranged and pastured, the life was totally different. It was determined by the buffalo itself. To some of the plains' tribes the buffalos furnished the chief motives in life. Villages moved as the herd moved from place to place. The hunting of the buffalo furnished the chief food of the popu-



CHEYENNE INDIANS *Photo by U. S. Office of Indian Affairs*
Chief Paul Boynton and family, of Oklahoma, seated in tepee.

lation; its skin furnished clothes and blankets and house covering; its bones gave material for implements and weapons; its horns were used in various ways. The *tipi* (tepee) or conical tent, consisting of a few light poles and a covering of skin, was a remarkable invention; it could be taken down and pitched again, ready for use, in a few minutes' time. It was the ideal home for people who would change location with the movement of the herd. The village of these tribes, consisting of a great circle of tents, was an idea adapted precisely to the situation. It was among these Indians that the sign language developed to high perfection. It was needed by the fact that peoples speaking different languages, coming from different tribes and different areas, necessarily met each other constantly when engaged in the pursuit of buffalos. It was among these tribes that we find the buffalo dance — an excellent example of mimetic, or imitative, dances.

In this dance the dancers represented the buffalos. It was celebrated at times when no herd was near at hand and the people needed food. Its purpose was to bring a herd of buffalos. The dancers drew buffalo skins over their bodies and upon their heads wore buffalo horns. They went through the movements of a herd of buffalos, while some of the tribe or village pretended to hunt the imitation animals. The idea was due to the fundamental thought of imitative magic. It was believed that by pretending to be buffalos and pretending to hunt the animals, real buffalos would be forced to come and a real hunt might take place. Such a dance was actually kept up until a herd of buffalos appeared, when, of course, it was believed that success had attended the ceremony.

In the Southwest, in the deserts of New Mexico and Arizona, we find the Pueblo Indians with their mode of life dictated by their surroundings. The great community houses of stone or clay, rising to several stories and composed sometimes of hundreds of rooms; the dress of rabbit skins, or native woven local fibers; the arts of pottery making, basketry and weaving; the religious dances and great secret societies; these and all other curious details of Pueblo life are closely related to the opportunities and limitations of desert life. The adaptation is so complete and interesting that it is no wonder that many students have gone to the Southwest to study its features, and that artists never tire of representing its details.

Again in the district of the Northwest Coast, the narrow stretch of country lying west of the mountains and extending from the Columbia River to Sitka, in Alaska, is a district which has impressed itself upon the native life and dictated its features. Here we have long villages of well-built wooden houses, stretching along the beach and facing the sea; here are the totem posts and memorial columns, carved with strange figures; here are the great canoes dug out of single tree trunks, but of such size as to carry scores of persons, who made long voyages to the interesting markets that were formerly held in the

Photo by U. S. Office of Indian Affairs

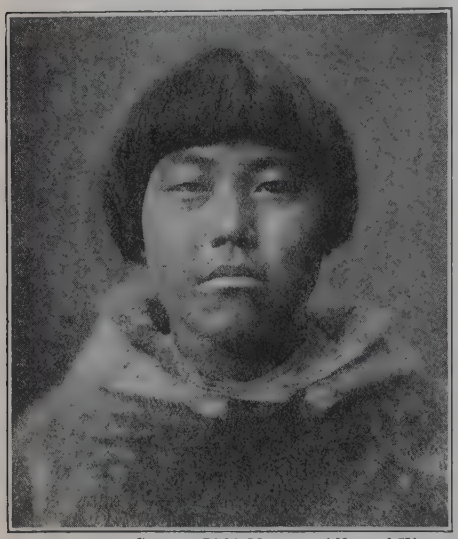
APACHE MOTHER AND BABE

This picture shows the distinctive Apache basket.

important towns. This is the district of blankets, beautifully woven from the wool of mountain sheep and the hair of mountain goats, or from the soft and flexible fibers of the bark of giant cedars; here were developed great secret societies and curious ceremonies.

Looking farther south in Mexico and Central America, we find a wonderful variety of life and customs,

ranging from savagery to the highest forms of barbarism. Among the Aztecs and Mayas of the Mexican Plateau and Yucatan, we find the highest cultures of American Indian tribes. A whole library of books has been written in regard to the religious rites and ceremonies, the magic practices, the time reckoning and the calendar of these remarkable peoples.



Courtesy Field Museum of Natural History
ESKIMO
Said by Professor Starr to be an unusually fine Eskimo type.

THE INGENIOUS ESKIMOS

It is difficult to say where to class the Eskimos. They live in the far North, along the waters of the Arctic Ocean; they extend from Greenland on the east into northeastern Asia. More of them live in America than in the great Asiatic continent. They furnish a marvelous example of adaptation to surroundings. The Eskimos, living in one of the most niggardly of environments, with the greatest disadvantages, have developed a culture remarkable in its details. It is, however, the Eskimos as a racial type that here interests us. They are little people, much below the average stature of mankind. Their color, features, broad faces and slanting eyes, remind us of the Mongolian, and it has been common to class them in the great yellow race. But the Mongolian has the broadest head of all the great races of mankind, while the head of the Eskimo is long and narrow. Some writers, on account of the Eskimo living for the most part in America, since he comes into contact with American Indians, and because he has often mixed with them, have classed him with the American Indian type. We will not decide the question.

THE MANY RACIAL TYPES OF EUROPE

The continent of Europe is often spoken of as the continent of the white man. It is true that the entire continent is occupied by Caucasic types. We find, however, a great diversity in the population. There are fair whites and dark whites. Not only so, there are many types of the dark whites. Professor Ripley has written an interesting and valuable work about the races of Europe. He recognizes three races in the population of the continent, and calls them by the names Nordic, Alpine and Mediterranean. In reality the case is not so simple. There are great numbers of Europeans, Caucasic in type, who do not belong to any one of these three groups. Deniker, a French author, who has made a thorough study of the peoples of Europe, carefully describes ten different race types in that continent. Personally, we prefer his classification to Ripley's because it really provides for the entire European population. So many writers, however, have accepted Ripley as their chief authority, that we will confine our attention to his three types. The Nordic type is tall; it has a long and narrow head; its skin is fair; the hair

A FEW OF EUROPE'S MANY RACIAL TYPES

A TYROLESE
From the old town of Innsbruck. A splendid type of the Tyrol region is this old street cleaner.

FINNISH GIRLS
National dress of the Vasa district.

POLISH GIRL
A peasant type.

DANISH TYPES
From the famous Danish painting "Two Fishermen from the Scow," by Michael Ancher. The hardy, rugged faces of these two men are extremely realistic.

TURKS—In Constantinople. The water carrier is a familiar sight.

BOHEMIAN CHILDREN
Two members of the Bakule Chorus, a group of Czechoslovak singers who toured America under the auspices of the American Junior Red Cross. They came to America to express their gratitude for aid given to Czechoslovakia by the 5,000,000 boys and girls of the American Junior Red Cross.

MORAVIAN GIRLS
Moravia, once a crownland of Austria, is now part of Czechoslovakia.

is light; the eyes are blue. It is a remarkably definite and well marked type. It forms a very large part of the population of Europe around the Baltic Sea. It is the prevailing type of Sweden and occurs abundantly in Norway, Denmark, Holland, Belgium, Germany and Russia. A very large portion of the blood of England comes from this race type. At the present time, the Nordics are influential in world politics. Large areas of Asia and Africa are held as colonies by Nordic peoples. The Nordic race is an aggressive, fighting population. The Alpine is a sharp contrast to the Nordic type. Shorter of stature, it is stouter and thicker set; the head is broad and short; the features are less sharp and cruel; the color of the skin is darker, brunette; the hair is brown of various shades, or black. The type is notably industrious, ingenious and inventive. It is probable that a large amount of the present supremacy of the Nordic type in politics is due to the inventions and discoveries of the Alpines. It is sometimes thought that the Alpine race is an entry from Asia. Its broad head, its industry, its lack of conquering energy—using the word in a bad sense—suggest the Mongolian rather than the Caucasian. The Mediterranean type is of medium stature, and of rather light and delicate structure; the head is distinctly long and narrow; the skin is dark; the hair, which is notably wavy and often tends to curliness, is black, and the eyes dark brown or black. The type seems to be notably artistic, fond of music and of arts in general. It has great organizing power and ability. There is a tendency at present to contrast the Nordic with the other types of Europe, to their disadvantage. As might be expected this comes largely from Nordic students. It is not certain that all Nordic traits are admirable, nor that the present apparent supremacy of Nordics is to continue. All three of these great types have produced men of eminence and ability. It is only when each has its full opportunity that the best conditions can be expected. Time will prove whether the Alpine and the Mediterranean may not play as great a part throughout the future as the Nordic.

The truly Caucasian types of Europe — Nordic, Alpine and Mediterranean—speak languages that belong to a single family, the Aryan. At first sight French and German, English and Russian, Italian and Swedish look very much unlike. It is quite certain, however, that they have all come from a single parent language. In western and southwestern Asia we find Caucasic peoples of dark complexion who speak languages belonging to a very different family—Semitic. The Arabs are an example. They are unquestionably Caucasic in race type, but the Arabic language is so different from the Aryan that it clearly did not come from the old original Aryan tongue. There are a considerable number of Semitic languages, all spoken by dark whites. Some of the most interesting peoples of the past were dark whites and spoke languages of this family. The Hebrews, the Assyrians and the Phoencians are examples of such dark whites of Semitic speech. There are, then three great groups of Caucasic peoples that differ from each other in language. They are the Aryan speaking peoples of Europe, the Semitic peoples of Asia and the Hamitic peoples of northern Africa. In the Pyrenean district, where France and Spain touch each other, lives an interesting people called Basques. They speak a language different from all others, but are Caucasians. They present some interesting customs, and are of a notably

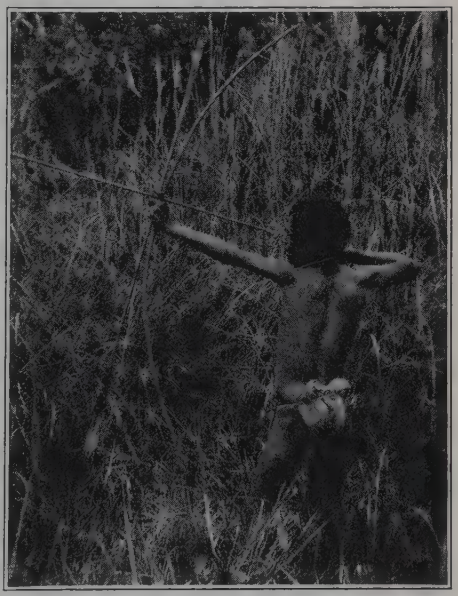
independent and enterprising character. Though few in numbers they have produced some famous men. Loyola, founder of the Jesuit order, was a Basque; so was the famous navigator, Magellan.

THE INTERESTING PEOPLES OF THE ISLAND WORLD

There still remains a great area of the world to be examined. It is as interesting as any of the continents which we have studied. We may call it the Island World. It includes the thousands of islands, of all sizes, that extend from Australia eastward through the Pacific to Easter Island. The populations of the Island World present a most interesting study. The three great races—Ethiopian, Mongolian and Caucasian—are represented in them. It is common to divide these island groups into several divisions known as Australasia, Malaysia, Melanesia and Polynesia. Each of them has its own types. We have already spoken of the peoples of Australasia, and will say no more of them. In Melanesia we find populations of big blacks. They are as truly negroes as those of Africa. They are tall of stature, very dark in color, have woolly hair, thick lips and broad noses. The tribes of New Guinea and of many islands to the eastward, as far as Fiji, are of this group. In Malaysia we have the true Malays. You remember that most writers nowadays include them in the great Mongolian or yellow race. They are of medium stature, yellow-brown in color, with coarse, straight, black hair, black eyes and flat broad faces. True Malays are found in the Malay Peninsula, in parts of Sumatra, in Java and in the Philippines. The Polynesians live farther East. The Maori of New Zealand, the Samoans, Hawaiians and Tongans are examples.

The Polynesians are usually greatly admired by Europeans and white Americans. They are frequently of great stature, well proportioned, strong and vigorous; their faces have features much like our own, but their complexion is a fine, dark brown. Their eyes are liquid and expressive and the hair is wavy.

It would be a great mistake to think that, even in these areas, we find only a single type. We, in the United States, should be particularly interested in the peoples of the Philippines. When we come to examine what they are racially, we find several well-marked groups. Just as in Africa we found big blacks and little blacks, so in the Island World, we find big Melanesians and small Negritos. There is good reason to believe that the first people who lived in the Philippines were Negritos. They are like the Pygmies of African forests. Short, rather slight in build, they have the



NEGRITO HUNTER
An interesting type from the Philippine Islands.

dark skin, the woolly hair, the features, the curious characteristic, the uneasy and restless face expression, of the little Africans. Like them too, they live in small groups, gain their food supply chiefly through hunting, build their poor villages in the neighborhood of towns of larger people, with whom they trade the wild products which they gather in the forest or get by hunting. In the mountain districts of the Philippines, we find a group of interesting peoples who at first were called Malays, but who today are generally known as Indonesians. There are many tribes of these, among which the Igorot and Ifugao are best known. It is believed that they are fundamentally Caucasic and related more nearly to the Polynesians than to the Malays, who form the chief population of the Philippines. These Indonesians are of medium stature or short, splendidly built, with rich dark brown complexions; with black wavy hair and dark expressive eyes. Though they are far from civilized in culture, they are industrious, and, to some degree, agricultural. They terrace the hillsides with their fields for rice. In fact, not even in China and Japan is the terracing of mountain sides for rice culture so notably developed as among these peoples. Far the greater part of the Philippine population is true Malay. We may say that at least eleven-twelfths of the population is such. We have already stated their physical type. Three hundred years and more they were under the control of Spain, and were profoundly affected by Spanish influence. They have long been civilized, educated, Christianized.

NATIVE HAWAIIAN

This old Hawaiian, member of a vanishing race, is making poi, the Hawaiian's staff of life, composed of pounded taro root.

Courtesy Field Museum of Natural History

JAVANESE DANCERS

The Javanese proper dwell in the central part of the island of Java. They are true Malays. They have marked aristocratic tendencies. The group shown in this picture visited Chicago during the World's Columbian Exposition in 1893.

Thus we have gone the world around in our inspection of human races and peoples. It has been impossible to speak in detail. We have been obliged to omit all mention of many interesting peoples, but we have tried to give you a general view of the peoples of the world. Our survey has been geographical. We have examined the populations of one area after another. In closing, we present on the following page a little table of the more important races and peoples. Here again hundreds of names are omitted, but the table will serve to show you how mankind is divided, and how the different peoples are grouped in order to show relationships.

Editor's note: The reader will find illustrated many other racial types in Volume V of this series.

TABLE OF RACES OF MANKIND

Race	Location and Subraces	Examples
A. **ETHIOPIAN, or black:** medium to tall stature; dark-brown or chocolate in color; head long and narrow (less so in Bantu); nose, wide and low; hair black, flattish in cross-section, wooly.	In Africa: true negroes	Sudanese, Wolofs, Kru
	Bantu peoples	Swaheli, Zulu, Bakongo, Bakuba
	In Island World: Papuans	
	Melanesians	Fijians, Solomon Islanders
	Australians	
	Tasmanians	
(*a*) Little blacks	In Africa: equatorial forests	Pygmies
	Kalahari Desert	Bushmen
B. **MONGOLIAN, or yellow:** short to medium (some tall); color, brown with yellow tinge; head short and broad; face wide and flat, nose often small and flat; hair coarse, round in cross-section, straight and lank, black.	In Asia: northern Mongols	Tungus, Kirghiz, Saomyedes, Manchus
	southern Mongols	Koreans
		Japanese
		Chinese
		Tibetans
		Burmese, Siamese
		Malays of peninsula
(*a*) Malay subtype	In Island World: Malaysia	Javans
		Filipino Cristianos (Tagals, Visayans, Ilocanos, and others)
Eskimos	In Asia and America: Arctic	
C. **AMERICAN (Indian), or red:** medium (or even short) to tall; color, brown with red tinge ("copper-colored"); face wide with prominent cheekbones; nose large, prominent, of moderate width; head form medium, though variable; hair coarse, round in cross-section, straight, lank, black.	Throughout North America and South America	Tlingit, Haidahs, Tsimpshians, Kwakiutls
		Chinuks
		Tinnehs (Dene), Navajos, Apaches
		Sioux, Crows, Winnebagos
		Crees, Chippewas, Delawares, Shawnees
		Iroquois, Cherokees
		Creeks, Seminoles, Choctaws
		Pueblos
		Aztecs, Mayas, Incas
		Caribs
		Botocudos, Tehuelches (Patagonians)
D. **CAUCASIAN, or white:** stature, medium to tall; color, ranging from fair to dark brown; head form, varies, but is usually not extreme, in narrowness or breadth; nose narrow, prominent; hair wavy, elliptical in cross-section, in color varying from light to black. Subtypes many and notably differing.	In Europe: Aryan in speech	Nordic
		Alpine
		Mediterranean
	Non-Aryan, isolated Finno-Tatar speech	Basques
		Finns, Lapps } physical type has
		Hungarians } "converged" to
		Bulgarians } Caucasian(?)
		Turks }
	In Asia: Aryan in speech	Armenians, Persians, Hindus
	Semitic in speech	Arabs
		Hebrews, Assyrians, Phoenicians
	Neither Aryan nor Semitic	Ainu
		Miatoze, Lolos
		Todas
	In Africa: Hamitic in speech	Berbers, Fellahin
		Libyans, Ancient Egyptians
	In Island World: Indonesians	Battaks, Dyaks, Igorot, Ifugao
		Hawaiians, Samoans, Tongans
Dravidians	India	Suggestive in some ways of Australoid connections

Note: During the last three hundred years Europeans (Caucasians) have streamed out over the world and crowding upon the native peoples have displaced or submerged them in North and South America, Australia and large parts of Africa and the Island World.

Book *of* The Human House

Life and Living Things
Plan of the Human House
Cells and Cell Life
The Nervous System
Nutrition
Circulation
Respiration
Excretion
The Skin
The Special Senses
Muscles and Bones
Food Values
Safety Problems

Field Museum of Natural History Photo

TEEMING LIFE IN A DENSELY POPULATED "BIRD CITY"

This photograph shows how sea-birds to the immense total of nine million a year flock to Walrus Island in the Pribilof group of the Bering Sea. Here safe from destructive animals of prey the birds rear their young.

LIFE AND LIVING THINGS

ALL living things are either plants or animals. All *plants* grow in their places and have no motion but a slow growing movement, except that some flowers close in the evening and open in the morning. Most green leaves and some flowers turn slowly to present their upper surfaces to their source of light.

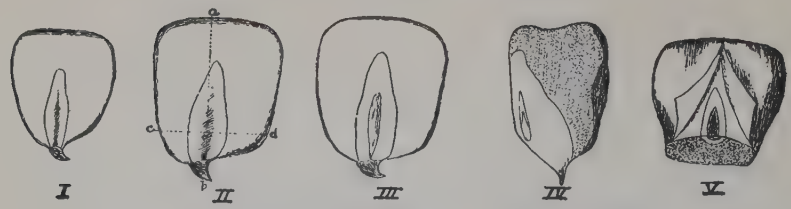
But *animals* move from place to place, walking, running, jumping, climbing, flying, swimming, crawling or creeping. They have arms, legs, wings or fins for use in their movements. They have eyes to see their food or to note danger. The beasts and the birds also have ears. All animals that have ears have voices. The cow calls her calf, and it hears and responds. The bird sings to his mate, and she listens and is entertained. Beasts, birds and insects can smell and taste, and all of them have the sense of touch or feeling.

As we have all these organs and senses we recognize that we also must be animals. Man is the highest of the animals. It is true that many animals can run faster and farther than any man can run. The keenness of scent of the hunting dog fills us with wonder. But the lower animals do not think things out nor talk things over. A dog can count only about three; and an ape or an elephant can count not more than four or five; but we count into the millions. We carry on conversations, we write descriptions or stories, we reason about matters. We accomplish these wonderful things with our brain. The beasts, birds, reptiles, frogs and fishes have brains; but the brain of man is much larger in proportion to his body than is the brain of any other animal.

It is important that one's body—the human house—should be well built and in perfect condition, if one is to live comfortably in it. Also it is important that the parts of the body that are used as tools and instruments—the legs, arms, feet, hands, mouth and tongue, and the many organs within the body—be in perfect condition. As a carpenter cannot do good work with rusty, dull tools, so we cannot do good work with weak, lame or unpracticed hands.

How a plant lives and grows

Plant four kernels of corn in a dish of



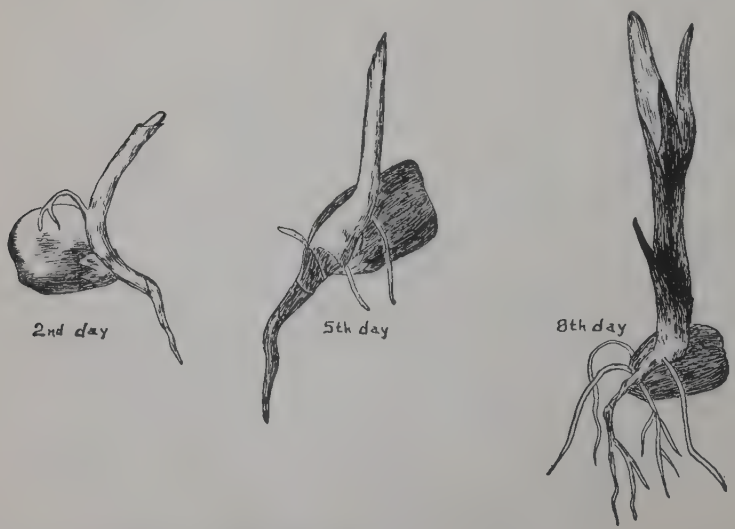
THE NEW LIFE HIDDEN IN A GRAIN OF CORN

The dry grain of corn (I) when soaked expands (II). In III is shown a thin slice of the kernel. In IV the kernel has been cut along the line *a b* of II. In V it is shown cut along the line *c d*. With the skin of the kernel peeled up we can see the new plantlet lying in its little bed of food.

sand or soil that is kept wet and warm. Put four kernels in a dish that is kept wet and cold—as cold as possible without freezing. Leave four grains where they will be kept dry.

After a week or ten days examine one kernel from each of the three lots. The dry grain will appear unchanged. As shown in the drawing, the wet grain has swelled up, because it has absorbed water from the soil. The warm, moist grain not only has swelled up but it has sprouted or germinated. A little yellowish point is growing up toward the surface of the soil, and a little whitish root is growing down into the soil. See how it looks three days later, and again after another three days. After the plant comes through the surface of the soil it requires sunlight and it must be kept warm and moist.

What starts the little plant? In each grain there is a *germ*. In the dry kernel the germ is asleep and has been since the corn ripened and dried in the field. The warmth and moisture awakens the seed and it begins to germinate. During its first stages of life and growth it lives upon food which the mother plant prepared for it. Examine a dry grain. The germ lies in a cradle of white substance. This is starch in which are other food substances in proper proportions.



HOW THE CORN PLANT GROWS

The tiny, sleeping corn plant in the germ has been awakened by warmth and moisture. The three pictures show development two days, five days, and eight days after germination started.

As the mother cow feeds her baby with milk that is a perfect food for her calf till it can eat grass, so does the mother plant provide proper food to support the baby plant till it can take care of itself.

What the baby plant needs

While the little plant is developing its stem and pushing the stem up through the soil, and growing its roots and pushing them down into the soil, it must have food to build its parts and strength to move them. Its food must be for growth and energy. The food is the substance of the grain: starch, oil, nitrogenous substance (protein) and mineral matter, all in the kernel.*

The solid substance of the kernel has to be dissolved as the first step in its use. The starch of the grain is changed to sugar and dissolved in the moisture within the grain. The moisture, which we may now call sap, circulates through the little growing stem or shoot. The sugar is taken out of the sap by the growing shoot and is changed to stem-substance or leaf-substance which we call *cellulose*. Nearly all the stiff stem-substance or spongy leaf-substance of plants is cellulose. Cellulose is mostly carbon. Sugar is largely carbon. Starch is largely carbon. There has not been much change in the starch of the grain when it is built up into the stiff hard cellulose of the plant body.

What the older plant needs

The young plant had to have carbon and water and mineral substance. The older plant with green leaves spread open to air and light and with roots buried in the ground needs the same things, but it can get them for itself. You will readily see how it gets moisture and mineral matter from the soil in which its roots are buried. How does it get the carbon? That is one of the wonders of nature.

Animals breathe out or exhale *carbon dioxide*, a compound of carbon and oxygen. Animals must get rid of the carbon dioxide which accumulates in their blood, so they breathe in "pure air" with much oxygen and little carbon dioxide, and breathe out used air with less oxygen and much more carbon dioxide. But green plants use carbon dioxide. It is food for them.

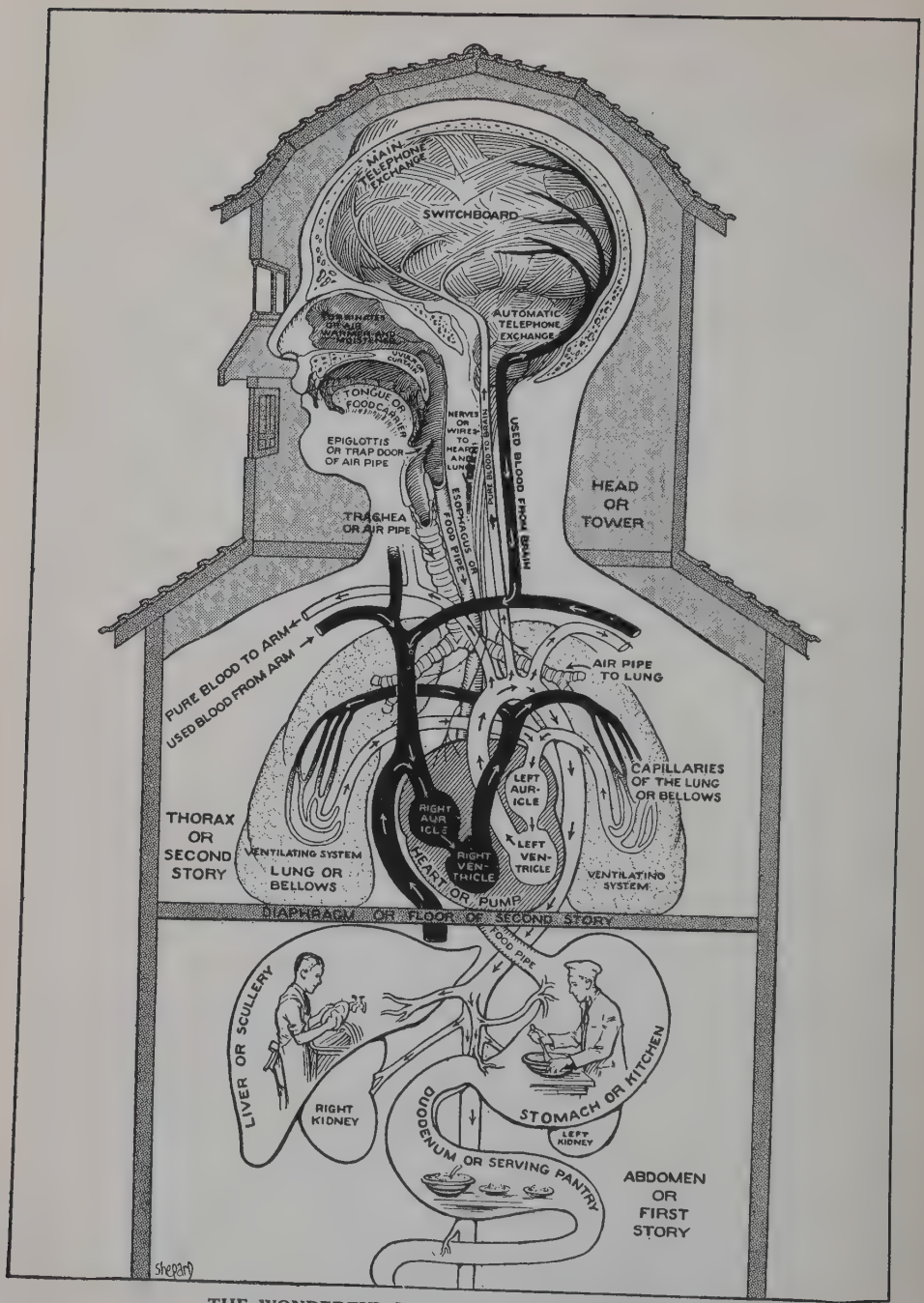
The green leaves of plants absorb carbon dioxide. It is mixed with the water brought up in the sap from the roots. The plant, with the help of the sunlight, can combine carbon dioxide and water to make sugar, which it changes into starch during the day. The plant eats carbon dioxide, but it actually uses only the carbon, while the oxygen is waste matter for the plant and is thrown off by the leaves that absorbed the carbon dioxide. At night when the plant has no sunlight, the starch in the leaves is changed back into sugar and is either carried in the sap to other parts of the plant to be used for growth, or stored up.

The relation of plants and animals

From what has been said, you see that plants use what animals throw off while animals use what plants throw off. Plants digest minerals and change them to a form which animals use. Plants eat carbon dioxide and water, and from these two substances make sugar, starch, oil and nitrogenous matter, all of which are used by animals for food.

Carbon dioxide is harmful to animals. As the plants consume it, they make the atmosphere more healthful for the animals. Thus animals owe a great debt to plants. Plants could not do these wonderful things if it were not for the sunshine. Thus we see nature helping all plant and animal life.

*Experiment: Burn a few grains of corn and finally all you have left is some white ashes, the mineral matter of the corn.



THE WONDERFUL HOUSE THAT BUILDS ITSELF

This is a general view of the most important parts of the human house that builds itself. There are two busy stories and a tower above. The telephone system in the tower is equipped with main and automatic exchanges. The white pipe lines carry pure blood and the black ones used blood. Trace the food from the mouth down through the food pipe to the kitchen. Close by is the scullery—a laboratory and scouring room. Just around the corner is the serving pantry or duodenum.

PLAN OF THE HUMAN HOUSE

APPROACHING the house in which a friend lives, you are interested in the general appearance of the house, and as you enter you notice the general plan. You are interested in the details of the plan and in the equipment of the various parts.

Look at the human house in which you live. It has two stories and a tower mounted on two sturdy columns or supports. The body of the house has a lower and an upper story. The lower story is the *abdomen*, the upper story the *thorax*, while the tower is the *head*. The column supports are the legs. The cow, the horse, the dog, the squirrel all have a body plan similar to yours, with head, thorax and abdomen. The parts of their houses, however, are on one level and mounted on four columns or legs instead of two.

The real you occupies the tower room or head. It is an observation tower with telescopes and cameras and other equipment to observe and study what is going on in the neighborhood. It has a sort of telephone exchange that keeps you in perfect communication with every part of your wonderful house. There are really two rooms in the tower. There is the observation room mentioned above, the brain cavity. Below that you will notice the mouth, which is a sort of entrance hall, and above it is an ample chamber through which the air used in the ventilating system passes. Turning again to the observation tower and the central telephone exchange where the real you lives, note the cables. Each contains many telephone lines that pass out to every part of your dwelling place. Through this wonderful system of communication you control everything. In the head are the brain cavity and the mouth and nose cavities.

In the second story or thorax are the lungs, the central organs of the ventilating system, and the heart, the central force-pump of the circulating system. In the first story or abdomen are various rooms and channels of the nutrition system, the stomach, duodenum, intestines and liver, where food is digested and absorbed, and the kidneys, where waste products are thrown out into the sewer system.

WHAT IS AN ORGAN

Let us now study our bodies from a different viewpoint. The animal body is made up of organs and systems of organs. What you see on the outside, the skin, which you can pinch and roll between your fingers, is an organ that does a very important work in protecting the body. The muscles and bones are under the skin of your arms and legs and the muscle-bone organs give us motion and locomotion.

An *organ*, then, is a special part of the body that does a special kind of work. The heart is a pumping organ that is the center of a *system* of organs, namely, the circulatory system that carries blood and lymph all over the body. Lymph comes from a Latin word meaning "goddess of water," and it is an almost colorless liquid. It contains colorless or white corpuscles, which we shall discuss later. The lungs form an organ, that, similarly, is the center of the ventilating or respiratory system. The stomach is the principal organ of the digestive system and the kidneys are the principal organs of the excretory system that throw out waste matter from the body.

WHAT ARE TISSUES

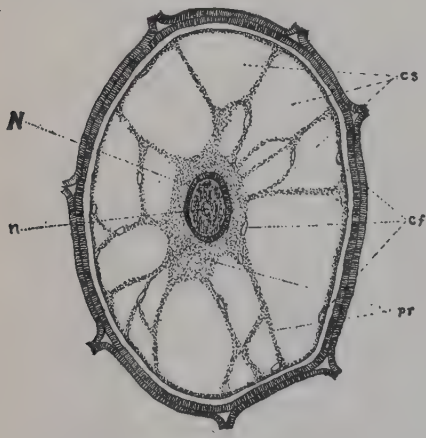
Every organ is built up out of *tissues*. The skin has an outer thin membrane, a tissue, that we call *epidermis*, from the Greek word *epi* (upon) and *dermis*

(skin), because it lies upon the real skin or *dermis*. The true skin or dermis is the middle layer. It is made up of strong, closely woven fibers. From the skins of animals this layer is made by the tanner into leather. Below the true skin (dermis) is a loose mesh work of fibers which holds the skin in place, although not too firmly, so that it can be pulled up into folds or slipped back and forth. Thus the skin is made up of three main tissues and several other special ones (hair follicles and glands) to be described later. In like manner every organ is composed of tissues.

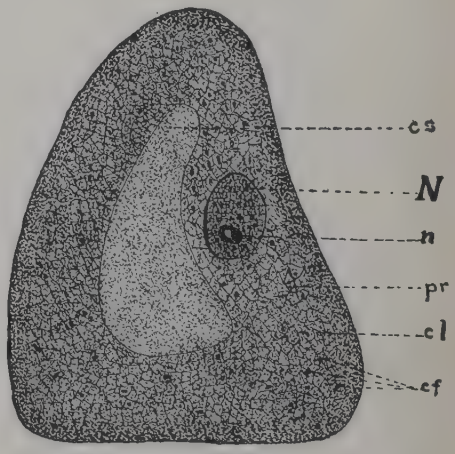
If one examines them with a microscope he will discover that every tissue is made up of many minute parts that we call *cells*. These tiny things that seem so large as we look at them through a microscope were named "cells" by the men who first studied plant tissues more than a hundred years ago.

The plant cell is really a tiny closed room that the living globule of plant matter makes for itself. The walls of this small room are cellulose. The students of living matter soon discovered that the cell was really only a little house that the living substance, *protoplasm*, had made for itself. Still they used the word "cell" to refer to the cellulose house and also the protoplasm living in it. Later "cell" was used for the protoplasm and whatever it makes, whether a wall outside or various structures inside as shown in the illustrations of plant and animal cells.

Every tissue is composed of cells. Every cell is a tiny globule of protoplasm, together with various things which the protoplasm prepares for its use. Inside the cell is a *nucleus*, or central part.

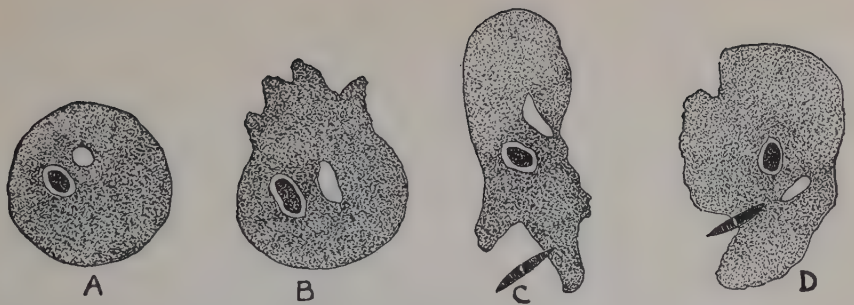


TYPICAL PLANT CELL (Bastin)



TYPICAL ANIMAL CELL (Wilson)

These are typical plant and animal cells. Note the protoplasm (p r), cell sap (c s), the granules of cell food (c f), the larger nucleus (N) and the smaller nucleus (n). In the inner protoplasm of the animal cell may be seen the cell lymph (cl).



AMOEBA EATING A DIATOM

The first picture (A) shows the amoeba resting; in B it starts out for something to eat ; in C and D it comes in contac with a diatom, which is swallowed through a mouth made for the occasion.

CELLS AND CELL LIFE

FROM what has been told you in the preceding article you know that a cell is the smallest division of living matter, the smallest living thing. It may be called a building block for the living house. Cells combine and build up tissues. Tissues are built up into organs. Organs, as a rule, are combined into systems of organs. The complete, perfect animal or plant body is composed of organs and systems of organs.

The simplest sort of cell is just a tiny globule or particle of living matter (protoplasm). The protoplasm is sticky, grayish, and granular and in the midst of it you will find the cell nucleus. Study carefully the drawings of typical plant and animal cells such as make up the bodies of plants and animals. Notice the granular protoplasm, the nucleus, the sap vacuole and the food particles, common to both plant and animal cells.

The amoeba in our sketch is shown eating a tiny plant, a diatom, that it has found in the aquarium. The amoeba must eat if it is to live and grow. After the amoeba has taken the small bit of plant protoplasm out of its shell, it will throw the shell out as waste matter. Thus the cell eats, digests, grows, moves, and throws out any waste matter that accumulates.

The amoeba is a living animal. It must breathe and so it absorbs oxygen from the water in which it lives and gives out carbon dioxide just as we larger animals do. The plants in the aquarium eat the carbon dioxide as described above and throw out the oxygen which the amoeba breathes in, thus completing the helpful circle of life described earlier in our story.

But all living things grow old, so the tiny amoeba grows to the full size for its kind. When it has grown up it must reproduce its kind, following the Creator's command in the beginning.

The picture shows how the amoeba reproduces. It simply divides in the middle, making two amoebas, each exactly alike, and each exactly like the mother when she was a young amoeba. These two daughter amoebas, which are twins, are just as hungry as was the mother when she was young, and they hunt for food, eat, digest and grow. When they become mature, each divides and reproduces just as their mother did. Then there would be four young amoebas, or two sets of twins. The next generation would have eight young, the next sixteen young, the fifth generation thirty-two young. How many young would there be in the tenth generation, counting the original twin daughters as the first?

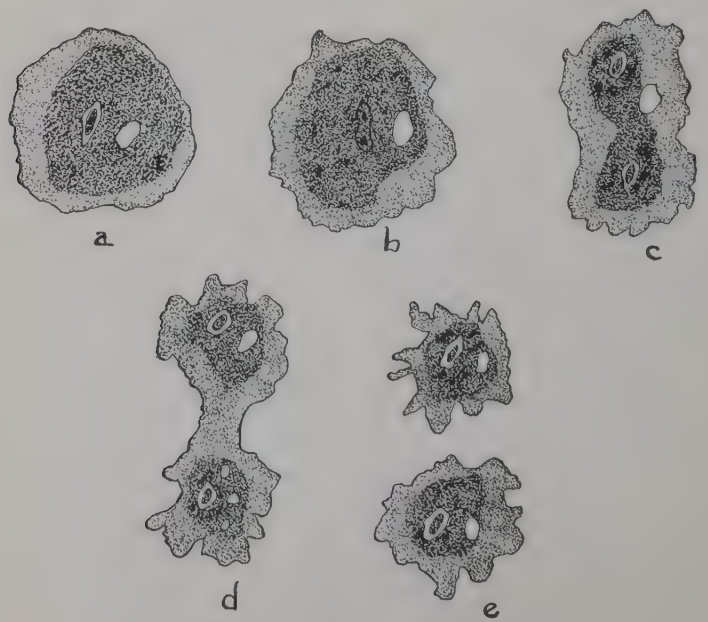
Did you notice that the mother amoeba did not die? She divided her substance equally between the two of the next generation and merged her life into their lives. Her protoplasm did not die; it was made young again, or, as we say, rejuvenated.

Let us sum up the things about life that we have learned in our study of the amoeba. Living things, animals and plants, must build up the matter they digest into new protoplasm. They grow, they breathe, they throw out waste matter, and finally they reproduce themselves.

THE RELATION OF CELL-LIFE TO THE LIFE OF ANY LARGER ANIMAL OR PLANT

We have just been learning how a single-celled animal lives its separate life. Do the cells that form your tissues and organs live a simple life? They do when they are young and the young body is developing and growing, but the cells in the body early become specialized. They become changed in form and in the work they do. The amoeba cell did not make anything but protoplasm. Plant cells make cellulose. The little cell of the diatom makes the shell that protects it. The cells in your body make cartilage and bone and tissue fibers and nerve fibers and digestive fluids and many other things that build up tissues and organs.

After an animal body is built up and while it is building or growing, the cells in different tissues and organs must do different work. Stomach cells in the glands that prepare digestive fluids must do that work. Muscle cells do their special kind of work. Nerve cells do their work. But what controls the work that different cells do? The body is a colony or community of cells. How is this community governed, and how are the individuals controlled?



REPRODUCTION OF AMOEBA (Hall)

An adult amoeba is shown reproducing by the simple act of dividing into two parts. Notice that each of the descendants has a share of the parent nucleus as well as a share of the parent protoplasm. Even the cell sap is equally divided.

THE NERVOUS SYSTEM

WE are now ready to investigate the marvelous telephone system that is in the human house. Its central office is in the tower.

We have found that the plant or animal body is a colony of cells. We have found that, like a colony of men, some of the individuals (cells) have one kind of work and some another. Another very important point of resemblance between the two colonies is the need for harmony of action between the different individuals of the colony.

In a human colony or state, there is always some central control. It may be a chief, a king, or a president, but in every case there is a controlling head to make decisions as to what to do next. This central control is always helped by others whose work is to assist in making decisions, or to announce the decisions to distant parts of the organization.

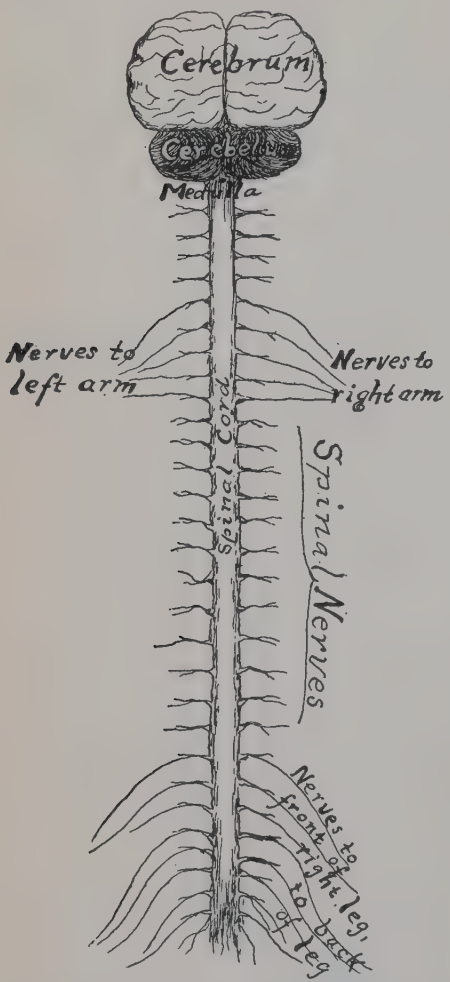
If a community of people were without these important leaders and helpers, there would be no unity of action in time of need. Who has not seen an excited company gathered at the burning of a neighbor's house—everybody giving orders which nobody obeys; everybody busy, but little or nothing accomplished. Presently a captain of police or head of a fire company appears upon the scene; he is experienced in the control of fires and of men. He begins to command; everybody gives heed and obeys. There is unity of action.

Think how impossible it would be to accomplish the work of a great railroad company, if there were not a central office in which plans are laid, decisions made, and commands issued. Through obedience to these commands every individual and every group of individuals employed by the company work together.

In a similar way the great number of cells which make up the human body must be controlled by some central power. Suppose the stomach should make the digestive fluid at a time when there was no food in the stomach. Suppose the glands of the mouth which make the saliva should not work when the mouth was chewing the food. Suppose that after the chewed food started down the esophagus, that tube should stop contracting; the dry food would stick in the esophagus and have to be washed down with water; the stomach, having already made its fluid and passed it on into the intestines, would be dry, so that the food would be moistened only by the water which came into the stomach with it. The food would not digest, but would fer-

ment in the stomach and make the person ill.

So we see the absolute necessity of having some contrivance for controlling the action of all of the organs, systems of organs, tissues and cells. When this control is perfect, the body remains in good health; but when some portion of the body, even if it be a small portion, fails to obey the commands issued by the central governing organ, the whole system is likely to become deranged and the body to become ill.



BRAIN AND SPINAL CORD

The brain is composed of the cerebrum and the cerebellum, shown here in a back view. The medulla is the wide upper end of the spinal cord. Spinal nerves in pairs branch off from the cord. Some of these spinal nerves are united in nerve cables that go to the arms and the legs.

The central governing organ of the body is the *brain*. The brain is assisted by the *spinal cord* and by various organs which collect news and carry messages. The brain with the spinal cord and the nerves is the *general nervous system*.

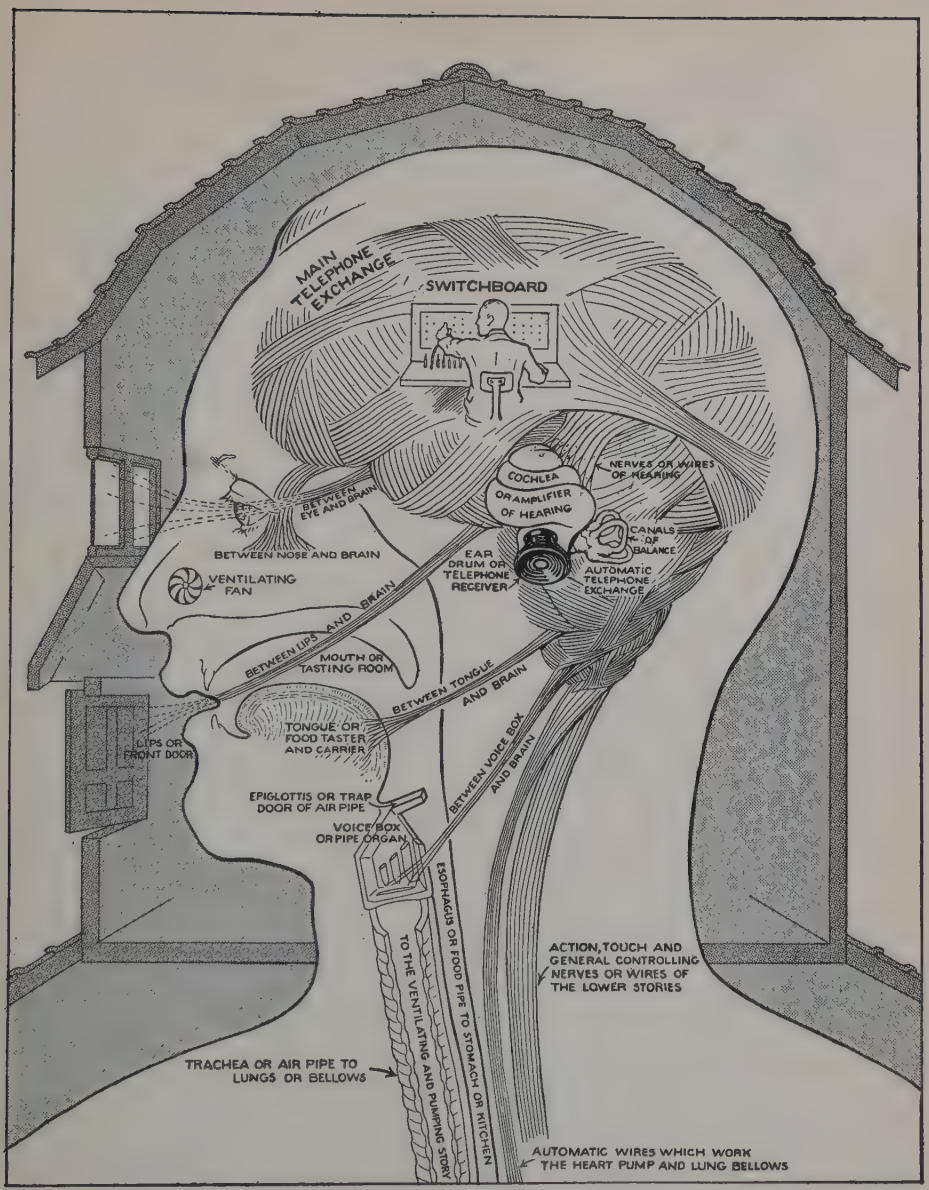
Structure of the Nervous System

In bringing unity of action among those who work for a great railroad company, an army or other large community of individuals, two things are necessary; (1) a central controlling power, and (2) communication from the center to all of the distant parts of the company, army or community.

In controlling the movements of trains upon the railroad system, messages are sent along telegraph wires to conductors hundreds of miles away, telling them what to do so that there may be no accident. If something unexpected happens in a part of the system, a message is sent to the controlling center, where action is taken.

In a similar way the animal body has a central controlling power in the brain. The brain is in constant communication with all parts of the body. Messages are continually being sent to all parts of the system. Telephone messages are sent over wires, but the brain sends and receives its messages over fibers which are as fine as those of a spider's web.

The telephone wire is not a part of the telephone operator, but the *nerve fiber* is a part of the operator whose station is in the brain or spinal cord. This operator is a *nerve cell*. The brain and spinal cord are composed of nerve cells with their fibers. Every nerve cell has a long fiber, over which it sends messages to other nerve cells, and

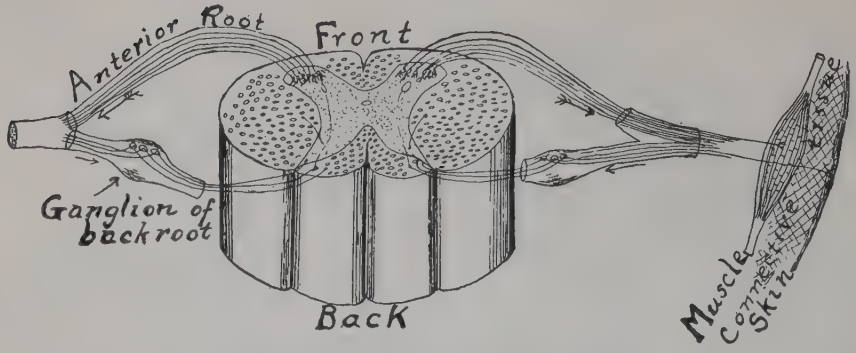

MAIN TELEPHONE EXCHANGE
SWITCHBOARD
NERVES OR WIRES OF HEARING
COCHLEA OR AMPLIFIER OF HEARING
CANALS OF BALANCE
AUTOMATIC TELEPHONE EXCHANGE
BETWEEN EYE AND BRAIN
BETWEEN NOSE AND BRAIN
VENTILATING FAN
EAR DRUM OR TELEPHONE RECEIVER
BETWEEN LIPS AND BRAIN
MOUTH OR TASTING ROOM
BETWEEN TONGUE AND BRAIN
TONGUE OR FOOD TASTER AND CARRIER
LIPS OR FRONT DOOR
BETWEEN VOICE BOX AND BRAIN
EPIGLOTTIS OR TRAP DOOR OF AIR PIPE
VOICE BOX OR PIPE ORGAN
ESOPHAGUS OR FOOD PIPE TO STOMACH OR KITCHEN
TO THE VENTILATING AND PUMPING STORY
ACTION, TOUCH AND GENERAL CONTROLLING NERVES OR WIRES OF THE LOWER STORIES
TRACHEA OR AIR PIPE TO LUNGS OR BELLOWS
AUTOMATIC WIRES WHICH WORK THE HEART PUMP AND LUNG BELLOWS

THE TELEPHONE SYSTEM IN THE HOUSE

There is a twenty-four-hours-a-day telephone service in the human house. Up in the brain there is a main exchange and an automatic exchange, and you are the operator. Messages fly back and forth between the exchanges and the windows, front door, ventilating fan and the pipe organ; the lower stories receive their orders and make their responses, and the work of the house is thus carried on.

every nerve cell has at least one or more nerve fibers, through which it receives messages.

When several telephone wires are to go side by side for a long distance, they are frequently bound together into a cable. In a similar way the nerve fibers which leave any one part of the brain or cord to go to the same general region of the body are bound together



CROSS SECTION OF THE SPINAL CORD

If one were to cut from the spinal cord a piece corresponding to one of the vertebrae, he would find the gray matter in the middle of the cord and the section presenting an H-shaped area. Nerves go from the front or top of the H to muscles, and nerves come back from the skin to the ganglion (relay station) of the back root, thence into the back of the H. From this place in the back of the spinal cord some nerve fibers go direct across the gray matter to communicate with the muscle (motor) cells of the interior root.

into a cable or, as it is called, a *nerve trunk*. Nerve trunks contain not several only, but many hundreds, of the fine nerve fibers. Along the course of the nerve trunk branches are given off, which distribute the nerve fibers to different muscles and organs or to different parts of the skin along the course of the main trunk.

Here we may see the general make-up of the nervous system. The brain, within the skull, is the controlling center. The spinal cord, which passes down an arched-over canal in the vertebral column, consists mostly of nerve fibers which carry messages to and from the nerve cells of the brain. There are relay stations all along the spinal cord where messages are received and sent out on their way to and from the brain. All of the lines branching off from the spinal cord represent trunks of nerves which lie between the muscles or under the skin of the body and limbs.

But there are also nerve trunks which pass from the spinal cord inward to the body cavity, to the thorax and abdomen. There is a double line of *ganglions* along the back side of the body cavity. A ganglion is a relay station made up of numerous nerve cells. These ganglions are about as large as peas or beans. Each of the ganglions in the double row, mentioned above, receives a bundle of fibers from the spinal cord. Some of these fibers bring messages to the ganglions from the brain or spinal cord, while some of them carry messages from the ganglions to the brain or spinal cord.

Each ganglion in the chain sends out nerve trunks to organs of the thorax or abdomen, or to large ganglions in the midst of the abdomen. These large central ganglions serve a purpose similar to that of the central exchange of a telephone system. They serve to put the organs into communication with each other. Through this communication the activity of one organ is responded to by the activity of another. For example, the presence of food in the stomach stimulates the stomach to begin the churning movements and to form the digestive fluid. This causes the pancreatic gland to begin its work of making digestive fluid for the intestine to use in its digestive work.

This nervous communication between the different organs of the body enables them to work together. Because of this, these nerves and gan-

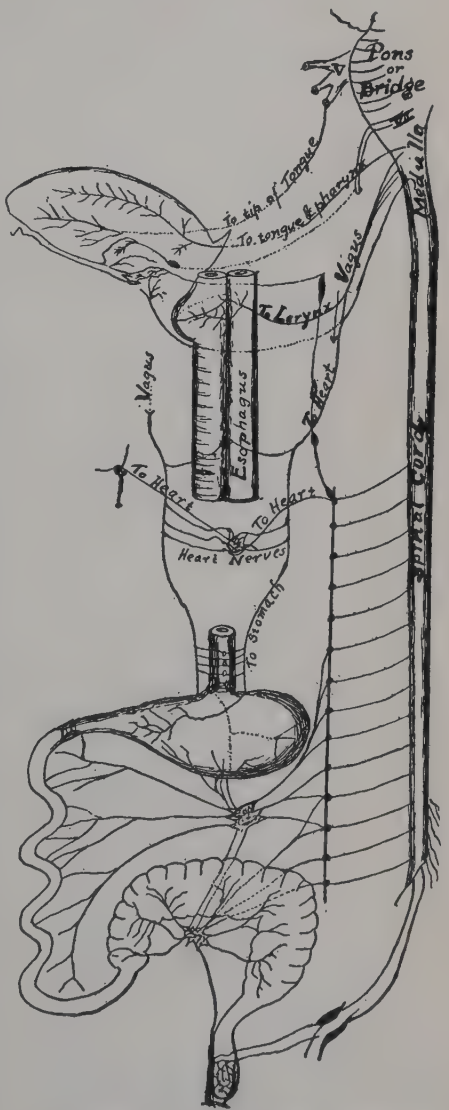
glions have been called the *sympathetic nervous system*. But because the action is largely independent and mostly within itself, we are now calling this part of the nervous system, the *autonomic*, or self-governing, nervous system. But remember that this part of the nervous system is simply a part of the general nervous system.

Through the influence of this autonomic nervous system, the disorder of one organ may cause the disorder of other organs.

Reflex action

We have learned that there are relay stations along the spinal cord. A message sent from the brain to the muscles of the arm starts from a group of nerve cells in the brain and follows its fibers down the spinal cord to a place opposite the shoulders, where the fiber ends in a little tuft of branches, which lie among the short branches of a nerve cell in the cord. The message is communicated from the branches of the fiber from the brain to the short branches of the nerve cell in the cord, and this cell relays the message along its fiber to the muscles. If the message tells the muscle on the front of the forearm to contract, the fist will double up. When one's brain sends such a message as that, one is conscious of it. Furthermore, one knows it before the brain sends out the message; so that one can send it or not just as he chooses. This kind of action is called *voluntary action*, because one may do it or not just as he wills.

Why does one will to make a certain motion? Suppose he were hungry and had before him a piece of food. The eyes, and perhaps also the nose, would send messages to the brain; that is, he would see and smell the food. These sensations in the brain would arouse a desire for the food. Messages would be sent to and fro, from one cell to another in the brain; that is, he would begin to think about the food and his need for it, and finally, perhaps in a few moments, he would decide to take the food. Messages would be sent to vari-



AUTONOMIC (INDEPENDENT) NERVOUS SYSTEM

The heart, stomach, liver, pancreas and intestines must be controlled by nerves; but the control must not require thought and will on the part of the person.

Each organ is controlled from a relay station (ganglion), placed in or near it. These ganglions are connected by fibers with the central nervous system. Over these fibers messages are exchanged with the brain and spinal cord, and general sensations are received from the organs.

ous muscles; the arm would be extended, the food grasped, the arm bent and the food carried to the mouth, which would be opened to receive it. This is a very brief description of what takes place in the nervous system under such conditions. To describe it accurately and completely would require many pages. Before one stops to think about it, however, it seems to be the simplest thing in the world; so simple, in fact, that a little baby too small to talk or to walk will perform all the series of motions with faultless accuracy and grace.

Let us take another example. Suppose that one touches a hot stove. There are nerves of sense in the skin of the hand; messages are sent along the fibers to nerve cells which lie just outside of the spinal cord. From the cell a fiber carries the message into the cord and communicates it to another cell which carries it to the brain. When the message reaches the brain, one becomes conscious of the heat of the stove. Let us suppose that the heat is enough to make one uncomfortable, and to fear that the hand may be burned if it is not removed. Messages will be sent down the cord to the proper muscles, and the hand withdrawn. There we have another example of voluntary motion following sensation.

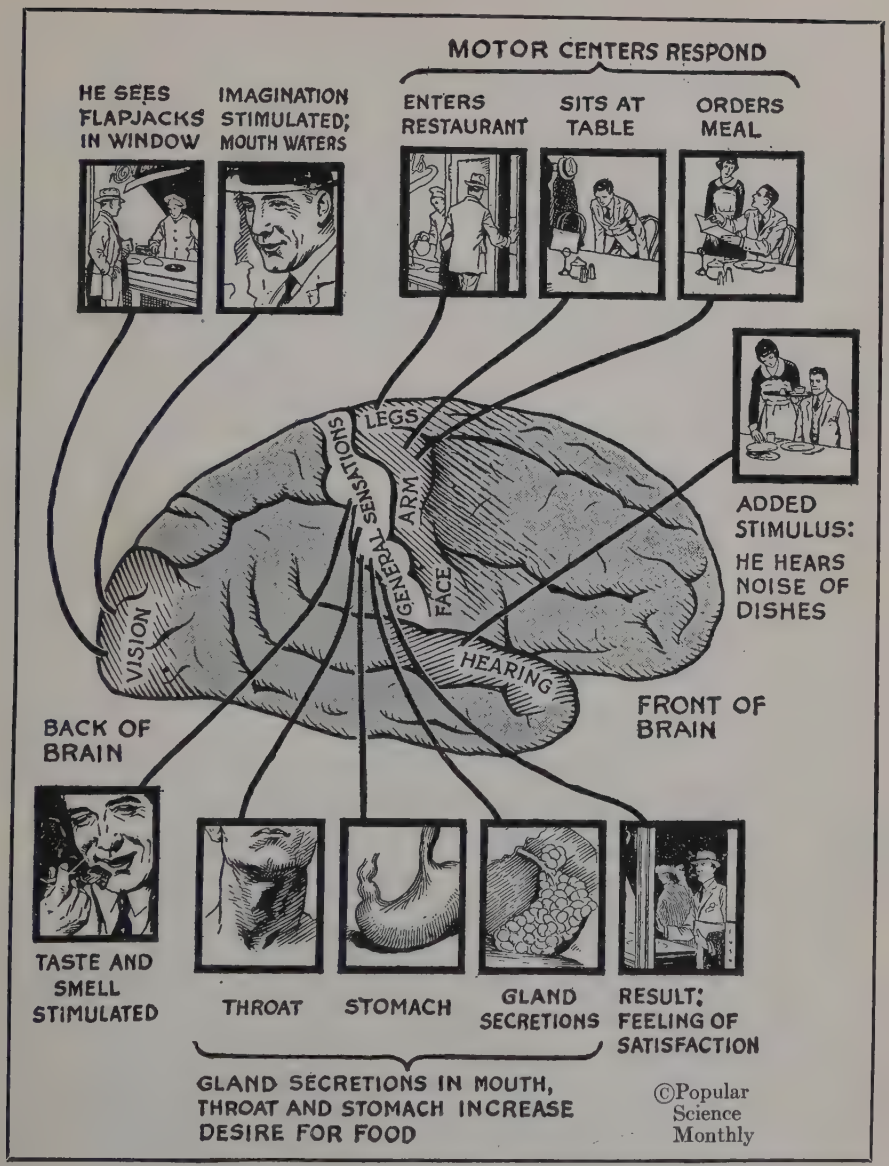
Now when the message of sensation enters the cord on its way to the brain, it follows a branching fiber, only one portion of which goes to the brain. The other portion passes across the cord, directly or indirectly, and communicates with the nerve cells which control the muscles of the arm and hand.

When one touches a hot object, the message which is sent to the cord on its way to the brain is instantly communicated across the cord, and the nerve cell of motion, without waiting to hear from the brain, sends a message back to the arm, causing it to contract and remove the hand from danger. This saves time and usually lessens the damage done to a part of the body. An instant later the brain is fully conscious of all that has happened. One knows that the hand has been burned, and that it was jerked away before the brain was consulted; but one always approves of the action. This intervention of the cells of the spinal cord in cases of emergency is called *reflex action*. Note carefully the drawing, and study out how the messages are sent.

The term reflex action has an application somewhat wider than simply to cases of emergency and danger. When one is learning to perform a new series of movements, such as walking, skating, riding a bicycle, writing, or playing a musical instrument, each movement is a voluntary one. Of course, if on skates or on a bicycle for the first time, one is likely to make a good many involuntary motions, but they are extra and unnecessary, though they may be a usual part of the beginner's exercise. The whole attention is required to direct the movements of the body and its different parts. Each movement is likely to be slow and awkward, but after it has been made hundreds of times it requires less attention and is more graceful and accurate. Finally, one may make long series of motions without giving them any attention whatever. Walking, skating, cycling, writing, or playing a piano or violin eventually become automatic or mechanical.

Automatic action and habit

What is *automatic motion?* The will and the thought are usually involved, but in quite a different way from that which is observed in the beginner, who must study the details of every movement made. The practiced musician reads a measure or phrase of his score



HOW THE BRAIN CONTROLS THE BODY

This picture story shows how the brain receives messages from the outside world and then tells the body what to do. The man receives impressions in the vision center of the brain and his imagination is stimulated. He imagines himself eating flapjacks and the thought stimulates the senses of taste and smell and of certain glands in the throat and stomach. Through the secretions of the glands there comes an increased desire for food and his mouth waters. Next we see the motor centers responding and the muscles act to satisfy the hunger.

and wills to execute it as a whole, while the fingers fall into place more or less automatically to correspond with the thought in the mind of the player. In a similar way the writer thinks words, leaving the making of each word largely to the fingers. This is especially true of the shorter and more frequently used words. The less familiar and longer words require some attention. Writing with a typewriter becomes automatic; so also does the use of the telegraph instrument.

What is the difference between the first hard efforts and the final automatic regularity, speed, grace and accuracy? Practice has made one movement suggest the next, and once the combination of movements is willed and the series of movements begun, everything becomes reflex and extremely easy.

There is no property of our bodies of greater value to us than the reflex action that may become automatic. If it were not for this, we should have to give every step our whole attention. In fact, we could never learn to do anything gracefully, accurately and rapidly. We would always be awkward, halting beginners.

Very much like this automatic action of the muscles, depending upon reflex action, is a certain property of the nervous system which we call habit. Webster defines habit as "the involuntary tendency to perform certain actions, * * * an internal principle which leads us to do easily, naturally, and with growing certainty, what we do often."

A study of this definition of habit must make it clear that it cannot be very different from automatic action. Both are acquired gradually; both make it certain that a particular act or thought will follow unless the will power of the brain is used to stop it.

Habit has a wider meaning than automatic action and includes thoughts as well as muscular acts. One may cultivate a habit of generosity, or a habit of erect carriage while walking. One may cultivate habits of industry and habits of courtesy; habits of honesty and habits of gentleness. Every important function of the body and mind may be changed from the course for which it was intended by nature; it then becomes as great a curse as it was a blessing when rightly used. So it is with habit. One may get a habit of stinginess, or a habit of slouchy carriage while walking. One may get habits of laziness and habits of impoliteness; habits of dishonesty and habits of cruelty.

For every good habit there is a corresponding bad one. During youth one is always forming good habits or bad ones. One must do one or the other; he has no choice in the matter. Good habits are a safeguard during all later life; bad habits are persistent enemies. It requires years of settled effort to root them out after they are once established; but it is very easy to keep them out in the first place.

NUTRITION

LET us now look into the construction and the upkeep of the house we live in. This concerns foods and is called nutrition.

The term *nutrition* includes all of the work that tissues and organs do in the *digestion*, *absorption* and *assimilation* of food. Assimilation refers to the building up of food material into the living active tissues of the body, as well as to the oxidation (union with oxygen) of food material.

Why do we eat

If you have ever watched a locomotive in motion you must have seen the fireman putting fuel into the fire box. You know just as well as the fireman does that if he should stop putting coal on the fire the engine would soon stop going. He knows something which you do not know, namely, how much coal to use to make the engine go a given distance.

Many railroad companies and many large factories analyze coal before they buy, in order to know which coal will give the most heat and motion per ton or per dollar's worth.

The amount of heat and motion which a fuel produces can be exactly measured. The coal which is used in the locomotive becomes oxidized (burned) and changed into carbon dioxide and water with smoke and ashes left over. The oxidation of the carbon of the coal causes heat to be given off. The heat under the boiler produces from the water steam, whose pressure in the cylinders moves the pistons and turns the wheels. The engine itself is not built up by the fuel which it consumes; so gradually it wears out.

We take food into our bodies to supply heat and motion, and if the food be tested we can tell exactly how much heat and motion it will give. In the government laboratories at Washington and in many other places are scientists at work finding how much energy can be obtained from different foods when prepared in different ways. Food will give about the same amount of heat and motion when burned in a furnace as when consumed in the human body.

In selecting coal the buyer chooses that which gives the most power for the money, without regard to the looks of the coal or the color of the flame. In choosing food to supply our bodies with heat and motion what should we think of first? Should it not be the amount of power it contains? In other words, food should be chosen to give the most nourishment for the least money, provided it looks appetizing and tastes good. Here comes in the work of the cook, who can choose and prepare the food and add the seasoning and the decoration.

We should think an engineer very wasteful if he used more coal than necessary to make his engine do its work. Is it not equally wasteful for us to eat more than we need for our work simply because it tastes good and we enjoy it?

That which is harmful should not be eaten, although we may like it. That which is nourishing should often be taken, even though we do not like it. If one thinks of the good which a wholesome and nourishing food will do the body, instead of thinking whether the taste is most pleasing to him, he may easily cultivate a real liking for a food which may at first seem distasteful.

In our study of foods we shall inquire, first, whether they have the building materials that the body must have, and second, how much fuel material each food has.

The value of eggs in nutrition

Let us first look at the egg of a hen, for in this we have what is to the animal world just what the seed is to the plant world. If we examine an egg carefully we find an outside shell that corresponds to the shell of a nut. Underneath the shell we find a tough skin similar to that which covers all seeds. Inside the skin is a white fluid and a yellow fluid which are the food. Just under the very thin skin of the yellow part, or yolk, we see a whitish spot with a ring around it. This is the germ or young chick. The young chick is surrounded, as is the young plant by the food which it will need when it awakens to life. Both the plant germ and the chick germ are sleeping protoplasm. They sleep until the heat wakens them to life. The seed needs also moisture to soften the food, but the egg is already supplied with enough water.

The yolk of the egg is so balanced that the germ spot is always up, whichever way the egg is turned. In this way the germ is kept next to the heat which the mother hen supplies from her body when she sits on the eggs. The yolk of the egg is protein and oil, with some mineral matter. The oil gives it the yellow color. The white of the egg is pure albumen, or protein with mineral matter and water. From these materials are built up the bones, muscles, blood, nerves and feathers of the hatching chick.

The egg is nature's food for young birds. Is it a good food for us? We need bones, muscles, blood, nerves and hair, and if the egg will build up these tissues in a bird, it will also build them up in us. It is, however, such condensed food that it cannot be used alone for the food of an adult, and only sparingly for a child under one year old. When the egg is raw it is easily digested, but when cooked it becomes hardened and is more difficult to digest.

Building with milk

Nature has supplied in milk a food for the young of higher animals. This food exactly fills the need of the young child and contains everything that a child requires for its first year's growth. Let us see what materials milk contains. The part that makes it liquid is water, the sweetness comes from sugar, the cream which rises to the top is oil, and the rest is protein* and mineral matter. You can see that milk alone would sustain life a long time.

Cereals, the food provided by the great grass family

Grains which are used for food are called cereals. They belong to the grass family, and form an important part of our food. Corn, wheat, oats, barley, rye and rice are cereals. From them we get corn meal, cornstarch, wheat flour, Graham flour, oatmeal, barley, rye flour, rice and rice flour and various other meals and prepared "breakfast foods."

If we look at a grain of any of the cereals we find that it has a skin covering the grain. Oats, barley and rice have a tough, chaff-like skin, which is always removed before it is put on the market for food. Barley and rice are so seldom seen with the skin on that we think of them as white grains. Under the skin of wheat, rye, oats or barley is a brownish or yellowish coat that is rich in protein and mineral matter. The inner part of the seed is mostly starch, containing some protein and mineral matter. Near one end of the kernel is the germ, which has much protoplasm and is very nourishing, being mostly protein.

Most of the protein part of these grains, especially wheat, is a sticky

*Protein contains carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus. It is muscle-building and nerve-building nitrogenous food.

VEGETABLES ARE VALUABLE TO THE HUMAN HOUSE

substance called gluten, and it is this gluten which makes many of the wheat breakfast foods seem sticky when cooked. In white wheat flour we have the starch, with some gluten and mineral matter. In "whole wheat" flour we get the starch and, from the brown coat, all the gluten and mineral matter, as this kind of flour is not bolted (sifted). In whole wheat flour we get all the contents of the grain and of the skin as well. There is no nourishment in this skin, but it makes the flour coarse and thus excites or stimulates the formation of digestive fluids as well as the movements of the stomach and intestines.

It is sometimes said that white bread is not nourishing. You can see that this is not a fact, but you can see equally well that the whole wheat or Graham flour contains material good for the whole body and especially for the bones and teeth for the greater part of the mineral matter lies in the brown coat which is mostly sifted out of the white flour. Growing boys and girls need much of the bone-making material to be found in whole wheat or Graham flour and in the whole cereal breakfast foods. Milk made bread is especially nourishing.

Care should be taken in the preparation of cereal foods, for unless they are well cooked they are hard to digest and some of the nourishment is lost. Some of these cereals are said to need "three minutes' " or "fifteen minutes' " cooking, but in every case the food is much improved in wholesomeness by at least thirty to forty minutes' cooking.

Macaroni (see article on "Macaroni" in next volume), which is made from flour and water and contains as much protein as wheat supplies is still largely starch, but when cooked with milk, butter and cheese contains all the elements of food, except cellulose and some of the vitamins.

The legumes—beans and peas

There is another group of foods which we call legumes. These are the beans and peas. They are rich in protein and starch and have some oil, mineral matter and cellulose. Like the cereals they form a complete food, but in such condensed form as to need supplementing with fruits and green vegetables.

Other valuable vegetables

There is still another class of foods which give nourishment in a much less condensed form and provide the variety which we need to give relish to our food. This class includes the green vegetables.

Let us taste in turn a bit of beet, turnip, parsnip, carrot and onion. In all of them we notice a sweet taste. We eat them for the sugar they contain and for the mineral salts, which we cannot detect by taste. They contain also a large amount of cellulose, which has no nourishment but which, by stimulating the digestive organs, helps them in their work. If we taste a piece of white or sweet potato, we shall notice that it is rough to the tongue and has a raw taste. This is due to the presence of starch. The sweet potato has also some sugar.

All of these vegetables which contain starch or sugar are very nourishing, but cannot be used alone as food, as they have almost no protein and oil. Because of lack of these substances, many vegetables are prepared with milk and butter in the cooking.

Cabbage, lettuce, radishes and celery are used largely as a relish and contain almost no nourishment. They are, however, very important as a relish and for their bulky cellulose; and some of them have other uses. Lettuce and celery have a juice that is soothing to the nerves. Spinach and other greens contain iron.

There are also some vegetable products that are very valuable as foods. Among these are potato starch, cornstarch, arrowroot, sago and tapioca, which are almost pure starch. The first is the extracted starch of the potato, the second of the corn kernel, while arrowroot and tapioca are from the underground stems of tropical plants. Sago is from starch deposited in the trunk of the sago palm.

The vegetable products that are sugar are beet sugar, cane sugar, grape sugar, maple sugar, molasses and syrups. All sugars and syrups, including molasses and honey, are very nourishing and for most people very wholesome. But these sugars, and the starches also, are not building materials at all. They are fuels, while the proteins are builders.

As potatoes contain principally starch, we usually add a little butter and milk to them or eat them with meat and gravy. Milk and butter are often added to beans, peas, parsnips, carrots, cabbage, celery and onions.

Food from the fruit basket

All the foods we have talked about, with the exception of milk and eggs, have been vegetable products, and the fruits also belong here. Such fruits as apricots, peaches, pears, plums, sweet cherries, grapes and some apples are eaten largely for their sugar and for their healthful effect upon the digestion. Bananas are rich in sugar but lack the refreshing juices of the other fruits.

Oranges, quinces and many apples, including crab apples, are chiefly valuable for their acid, although they also contain sugar. Lemons and limes have little sugar but are important foods because of the acids and salts which they contain. Fruit is especially needed in summer and in warm climates, while fats are needed in winter and in cold climates.

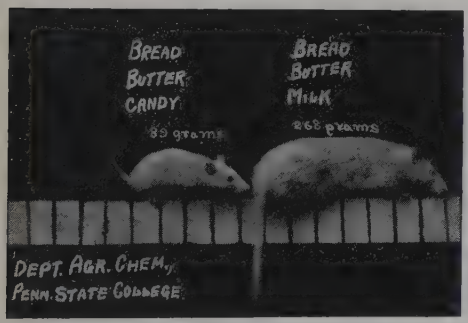
Meats in the diet

We have already seen that life could be sustained without any animal food. It does, however, contain the most nourishing kind of food in a condition easy to use. Meat is composed of protein and fat held together by connective tissues, such as bone, gristle and fibers. We are likely to think that porterhouse steak is more nourishing than

other cuts of meat that sell at half the price. If both are broiled it is true that the porterhouse steak will yield more nourishment, but the cheaper meats, by long cooking, become equally nourishing. The cooking changes the connective tissues (the fibres) to gelatine which is protein food. Have you noticed that when the water in which a soup bone has been cooked becomes cold it looks like jelly? That comes from the changed connective tissues, bone and gristle. (See article on "Meat Packing" in next volume.)

What are vitamins

But these are not the only good things to eat for growth and fuel.



A PRACTICAL LESSON IN NUTRITION

See how much better the rat that had milk in place of candy fared. Children will do well to drink more milk and eat less candy.

There are some more recently discovered substances that we now know are absolutely necessary for growth, health, and efficiency. We call these wonderful substances vitamins. The name was given by Casimir Funk, a Polish chemist. A vitamin is a sort of life-ferment. A ferment like yeast starts a chemical change, as a change of sugar into carbon dioxide and water. A very small amount of yeast will cause a large amount of change if given time. The yeast is not itself used up in the process. In a similar way we use in our bodies a number of these wonderful life-ferments or vitamins. Five or six deserve special mention.

Vitamin A causes and stimulates growth and development. It is found

WITH AND WITHOUT VITAMIN B

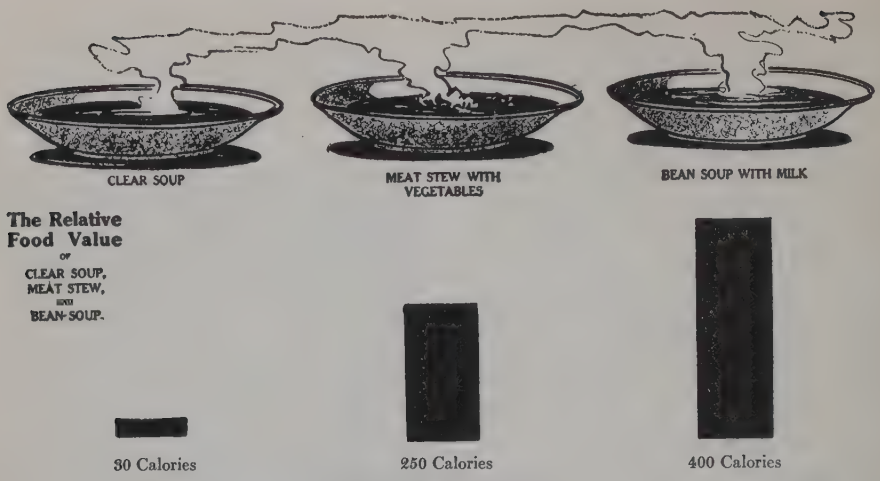
These rats were of the same age and came from the same litter. Both received the same kind and amount of food except that Vitamin B was present in one case and not in the other.

abundantly in halibut liver oil, also in cod liver oil, egg yolk, butter, cream, milk, and green leaves.

Vitamin B is more accurately known as Vitamin B Complex and consists in reality of two or more distinct vitamins. B, or B_1 is necessary to maintain growth, appetite, and proper digestion. It occurs in whole cereals, beans, peas, yeast, kidney, liver, and milk. B_2 (sometimes called Vitamin G) has been claimed to prevent pellagra, although this has been disputed. It may increase vitality. It is found in eggs, milk, and yeast. Vitamins B_3, B_4, and B_5 have been described but not universally accepted.

Vitamin C (cevitamic acid) is required for the normal development of the teeth and gums. Lack of it may cause scurvy. It is found in tomatoes, cabbage, lettuce, spinach, fruit juices, and citrous fruits.

Vitamin D (viosterol) aids normal development of the bones and teeth and prevents rickets. It occurs in halibut liver oil, cod liver oil, salmon,



THREE BOWLS OF SOUP ©A. I. C. P.

Make soup a worth while dish by using plenty of milk and vegetables.

egg yolk, sunlight, all fresh vegetables, butter and cream.

Vitamin E causes the animal to mature naturally and prepares it to reproduce its kind. If your pet rabbit fails to get plenty of green leaves in her diet she will not have any baby rabbits. This vitamin E is abundant also in the germ of cereals. It is also present in olive oil, cocoanut oil and lettuce.

As you study this important matter you see that egg yolk, fresh milk and cream, cereals which have the brown coat and germ left in the preparation (Graham and whole wheat flour) and greens (spinach and lettuce) are rich in the vitamins. Get eggs, whole milk whole cereals, green leaves and you need not worry for fear of any of the bad conditions mentioned above. Besides these staple foods mentioned above, one may well use fresh fruit, fruit juices, tomatoes, fresh vegetables and fresh nuts.

Making menus

Let us make some menus that will contain a healthful variety and yet give all the elements of food at a moderate price.

A BILL OF FARE FOR THREE DAYS

Breakfast
Fruit — Cereal Food — Toast — Milk

Luncheon
Omelet — Creamed Potatoes
Brown Bread — Apple Sauce

Dinner
Beefsteak
Potatoes — Spinach
Bread and Butter — Grapes

Breakfast
Fruit — Soft Boiled Eggs — Bread and Butter
Milk or Cereal Coffee

Luncheon
Made Dish of Rice and Meat
Prunes — Milk — Bread and Butter

Dinner
Baked Pork and Beans — Stewed Tomatoes
Baked Potatoes — Sliced Oranges
Bread and Butter

Breakfast
Milk Toast — Fruit — Cereal Coffee

Luncheon
Sliced Tomatoes
Cold Meat — Creamed Onions
Graham Bread

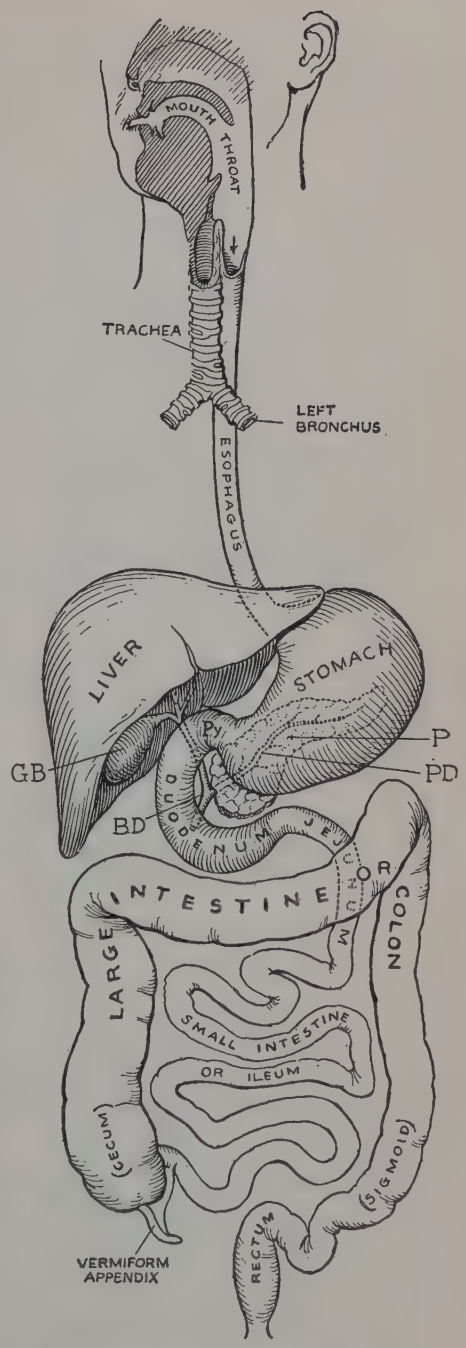
Dinner
Baked Macaroni and Cheese
Carrots — Baked Potatoes
Baked Apple and Cream

How the digestive system is made

The *digestive system* consists of the *digestive canal*, with certain *glands* whose ducts or tubes open into the canal. The digestive canal consists of a series of hollow or tubular organs, through which the food passes during the process of digestion and absorption. Beginning with the *mouth* the food passes down the *esophagus* into the *stomach*. After it leaves the stomach it passes through the coiled *small intestine* which is subdivided into the *duodenum* (sometimes called the second stomach), *jejunum* and *ileum*. Passing from the ileum into the *large intestine* through a small opening it comes into the *coecum*, then passes upward, across, and downward through the *colon* into the *rectum*.

The glands of the digestive system are the three pairs of *salivary* glands (the *parotids*, the *sublinguals* and the *sub-maxillaries*), the *gastric* glands in the wall of the stomach, the *pancreas* and the *liver*. The liver, however, has little to do with digestion and much to do with assimilation and throwing out of waste. Let us now look carefully at each of these organs of digestion and see how each is made and what part of the work of digestion each performs.

The *mouth cavity* is formed by the *cheeks*, the *lips*, the *tongue* and the *palate;* the latter has a front part, hard and bony, which extends back into a softer part from which the *uvula*, a sort of curtain, hangs down. Between the cheeks are the *teeth* whose work is to chew the food and mix it with the *saliva*. There are two sets of teeth, the temporary set of twenty teeth, which is lost at about six years and the permanent set of thirty-two teeth. There are three parts to a tooth, the *crown* or part seen in the mouth, the *root* or part which projects into the gums and the line between, which is called the *neck*. The teeth are composed of a

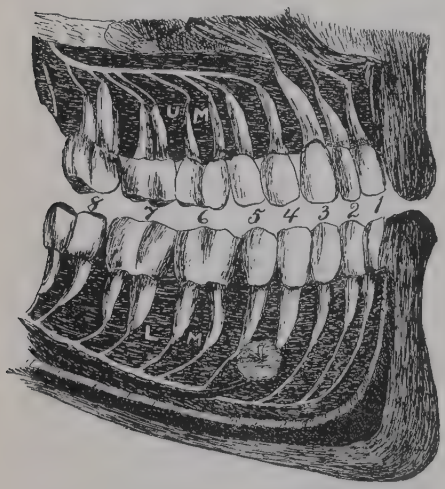


THE DIGESTIVE SYSTEM (HALL)

This drawing is diagrammatic and not exact in proportions. GB—Gall bladder; BD—Bile duct; Py—Pylorus; PD—Pancreatic duct; P—Pancreas (underneath stomach).

hard, shiny, outside layer called the *enamel*, which acts as a protection to the teeth, the middle bony part or *dentine*, and the inner soft part or *pulp*, largely composed of blood vessels and nerves.

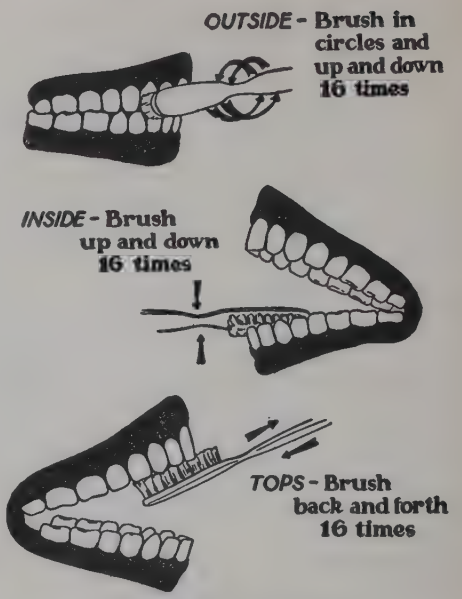
Beginning in the middle of the jaw, one finds on each side of each jaw two cutting teeth or *incisors*, one tearing tooth or *canine*, two semi-grinding teeth called *bicuspids* and three grinders or *molars*. Most of the teeth have a single root, but the molars have two and sometimes three roots or fangs.



THE JAWS AND THE TEETH

The Latin word for jaw or jawbone is *maxilla*. Here we see the upper maxillary (UM) and the lower (LM). In each side are eight teeth. The front teeth (1 and 2) in each half jaw are incisors, or "cutters," for biting. The canine tooth (3) is prominent in dogs and cats but not conspicuous in your mouth. Each of the bicuspids (4 and 5) has two cusps, or points. At the back (6, 7 and 8) are the molars, or "grinders." The exposed part of the tooth is covered with hard, glistening enamel. Note that the white nerve passes into the end of the root of each tooth. The main mass of the tooth is dentine (from a Latin word meaning "tooth").

The saliva, a digestive fluid, which mixes with the food during the chewing by the teeth, comes from three pairs of salivary glands: the parotid gland, situated near the angle of the jaw in front of the ear, the submaxillary, situated under the jaw, and the sublingual, under each side of the tongue. These glands make the saliva and pour it out



BRUSHING THE TEETH

These illustrations show the correct method of brushing the teeth. (From Baldwin's *Nutrition and Health.*)

when stimulated by the presence of food in the mouth, or even by the thought of food.

The *pharynx* is supplied with two doors which prevent the food from getting into the wrong passages. In order that the food may not go into the nasal passage, the uvula and soft palate turn back during the process of swallowing and cover the opening, and that it may not go into the air tube, a little guard, the *epiglottis*, protects the opening of the air passage. This is done very quickly for during the process of swallowing one cannot take breath. One does occasionally try to breathe and swallow at the same time with the result of getting food into the windpipe, causing violent coughing until it is expelled.

The esophagus is a long tube, which has a soft, mucous lining and a muscular coat of circular bands. In forcing the food along the esophagus the muscular bands do not contract all at once, but in succession, beginning at

the pharynx. The first contracts and makes the passage smaller and thus pushes the food on to be contracted upon by the next band. The same kind of motion carries the food along the whole extent of the digestive canal.

The stomach is a pouch, which holds about two or three pints. One opening between it and the esophagus, and another between it and the intestines, are supplied with circular muscles, which, by contracting close the openings. The end of the stomach near the heart is the storage part. The gastric juice, prepared by the gastric glands, does the work of churning and digesting the proteins.

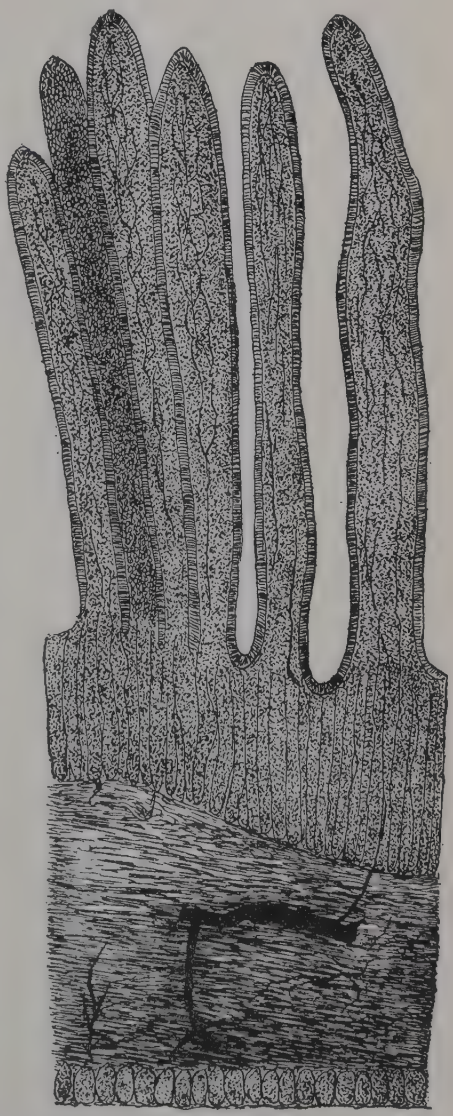
The stomach has four coats, an outside smooth coat, a second muscular coat which enables the stomach to contract and expand, an inner much folded coat of mucous membrane, and one between this and the muscular coat. In the muscular coat the muscles run both lengthwise and crosswise, and, by contracting first one set and then another of these muscular coats, give the stomach a churning motion. The inner mucous coat is thrown up in folds when the stomach is empty but these are flattened out when the stomach is full.

The gastric glands are situated in the mucous lining and pour out the gastric juice when food enters the stomach or when it usually receives food.

The pancreas is a long, spongy gland, which secretes the pancreatic juice and empties it into the duodenum.

The other intestinal juices are secreted by the *intestinal glands* which lie between the bases of the little finger-like projections called *villi*, and as the food is forced along by the wormlike wave motion of the intestine, it becomes digested and is absorbed by the villi.

The small intestine has, like the stomach, four coats, but the inner one, in addition to folds similar to those which we noticed in the stomach lining is also pushed up into the little villi, which very much increases the inner surface of the intestine. The food gets



THE VILLI

The six little finger-like projections shown here are villi (from the Latin word meaning "tuft of hair"). They line the small intestine, giving it a velvety appearance. The head of a pin would cover at least a half dozen villi. There are millions of them in the small intestine.

Digested food surrounds the villi, which absorb the food. The sugar and peptone go into the veins; the milky emulsified fats go into the lacteals which are found in the middle of each villus.

into the hollows between the villi and is in this way kept from passing so quickly through, and meanwhile the villi can absorb the digested material.

The large intestine is about four or five feet in length. There is little nourishment left in the food when it reaches the large intestine, so that its contents are chiefly refuse matter and water. The water is partly absorbed as it passes along and the refuse is carried away.

Three important digestive fluids

We called plant digestion the process of changing food to a form in which it can be used, and the same definition holds for animal digestion.

Plant digestion is partly carried on outside of the plant body by the roots of the soil, while animal digestion goes on within the body. Animal digestion is so thoroughly understood that it can be imitated outside the body and the process watched.

Digestion by saliva

We found that plants cannot use starch until it has been changed by a ferment. The same is true for animals. As the process goes on within the body, the mouth is supplied with a juice called saliva, which produces this change. Cooked starch can be more readily acted upon by the saliva, so all cereal foods, potatoes and other starchy vegetables should be cooked before being eaten.

When the food has been prepared it is taken into the mouth and masticated, or chewed, for two reasons: first, to grind it into small particles that can be reached by the saliva, and second, to moisten it thoroughly, so that it may be more easily swallowed and so that it will have enough of the saliva to make the change.

It is interesting to watch the process of digestion, and to find out just what the change is. Put into a glass tube a little cooked starch, some saliva, a little water and then, after shaking it, hold it in the warm hand for a few minutes. Now, if we put a few drops of iodine into the tube we shall find no blue color which proves there is no starch, but a purple color, which iodine always shows in the presence of dextrine, or half digested starch. We could go on and show that there is actually sugar present. Saliva, then, is a juice whose work is to change starch to sugar.

Digestion by the gastric juice

The saliva of the mouth acts upon the starchy foods, changing them to sugar, but saliva has no effect upon protein foods. Nature has supplied gastric juice in the stomach to do this.

The food, when swallowed, takes into the stomach a quantity of saliva which carries on the starch digestion for a while. The making of gastric juice is hastened by the presence of food. As it collects slowly, it gives the saliva time to go on with its work on the starchy foods.

If we test the saliva we find it alkaline like soda, but if we test gastric juice we find it acid like vinegar. You know that when we put sour milk and soda together one counteracts or neutralizes the other, forming a new compound which is neither acid nor alkaline, and which is known in chemistry as a salt. This is true of an alkali and acid. After enough of the acid gastric juice has collected to neutralize the alkaline saliva, the latter can no longer do any work. Then the gastric juice begins its work upon the proteins.

During the half or three-quarters of an hour in which the saliva can work, before the gastric juice has made the stomach too acid, only a portion of the starchy foods has been digested. The rest passes on into the intestines. If the food has been well cooked and

thoroughly chewed so that the gastric juice can get at every particle, the work goes on better.

Digestion by the pancreatic juice

Perhaps you have wondered what became of all the starch which the saliva did not digest and when you know that gastric juice digests only a part of the protein and that as yet there has been no effect upon the fats, you will see clearly the need for another digestive fluid.

When the food leaves the stomach it consists of the still undigested starch, the still undigested protein, the fats, mineral matter and water, besides the dextrine and sugar and peptone which have been formed by the saliva and the gastric juice. These all mixed together make a thin, pulpy, grayish mixture which we call *chyme*. The chyme leaves the stomach and enters the duodenum, the uppermost section of the intestine. Just at the entrance of the intestine is a tube from which the pancreatic juice enters the duodenum, and this juice, with the help of the intestinal juice and the *bile* (a fluid secreted by the liver), continues the process of digestion.

The pancreatic juice has three kinds of ferments, each of which has its own particular work. One ferment acts upon starch, changing it to sugar; one acts upon protein, changing it to peptone; and one changes fat into an emulsion, or into soap, which may readily be absorbed from the intestine.

The intestinal juice is secreted by the little intestinal glands that are located in the mucous membrane of the small intestine, between the bases of the villi. This juice contains one ferment which has the power of changing such sugars as cane sugar to grape sugar.

The bile, secreted by the liver, assists the pancreatic juice in making an emulsion of the fats and oils. The bile contains no ferment. The mucus which it contains in abundance lubricates the wall of the intestine, and so helps the food to slide along through the narrow canal.

The combined effect of these digestive juices is quickly noticed on the food. It is soon in a condition to be used in the body as nourishment.

How the digested food is used in the body

You remember that the starchy food was digested into sugar, the protein into peptone and the fat into soap. Starch, protein and fat are not dissolved in water, but sugar, peptone and soap are all soluble in water.

Starch could not be absorbed from the intestine into the blood, but sugar can be, because it dissolves in water. Thus digestion makes liquids of foods and prepares them to become a part of the wonderful human house.

Food carriers and absorption

The soluble parts of food begin to be slightly absorbed in the mouth (for tasting) but absorption takes place especially in the jejunum and ileum. You will remember that these are the coils of small intestine between the duodenum and the colon. The food is absorbed into the blood and lymph and carried all over the body.

The body uses the food—assimilation

By assimilation we mean the building up of food material into the body substance for growth or repair, also the taking of sugar and oil into the muscle cells to be used there for fuel. Picture the blood vessels carrying the food to every active cell of the body. Each cell takes from the blood, through the very thin capillary wall, just what it needs for itself.

The generating of life energy

Foods do not yield their energy to the body until they are oxidized.

Oxidation is the opposite of assimilation. Assimilation is a building-up process while oxidation is a tearing-down process. Assimilation requires energy to bring it about while oxidation yields energy. Motion, heat and light are kinds of energy.

Let us recall the life of the plant. It ate carbon dioxide and water, both very simple substances. In the leaf, inside the coloring matter (chlorophyll), the light of the sun (energy) combines carbon dioxide and water to form sugar. Oxygen is thrown out.

Sugar is a very complex substance. The animal eats the sugar and it is absorbed and carried to the muscle cells. The animal breathes in oxygen and the oxygen is carried to the muscle cell. The oxygen oxidizes the sugar in the muscle cell, changing it to carbon dioxide and water, and liberates the same amount of energy that the plant uses from the sun to build up the sugar. This liberated energy in the muscles will be partly in the form of motion but a large part of it is heat. The warmth of your hand is sunshine in another form.

The Hygiene of Digestion—Foods

Now that we know the elements of food and what value each has in the building up of the tissues, we are ready to think of the best methods of preparing foods, the best times for eating them and some other points regarding diet and health.

All starchy foods should be thoroughly cooked. It does not follow that all other kinds should be much cooked. For example, raw egg digests very quickly, while egg that has been cooked becomes so hard and so compact that the gastric and pancreatic juices cannot readily penetrate it to digest it.

Meat which contains much connective tissue must be cooked for a long time at a temperature just below boiling so that the connective tissue may be rendered in part digestible, but usually lean meat should be cooked only enough to make it palatable.

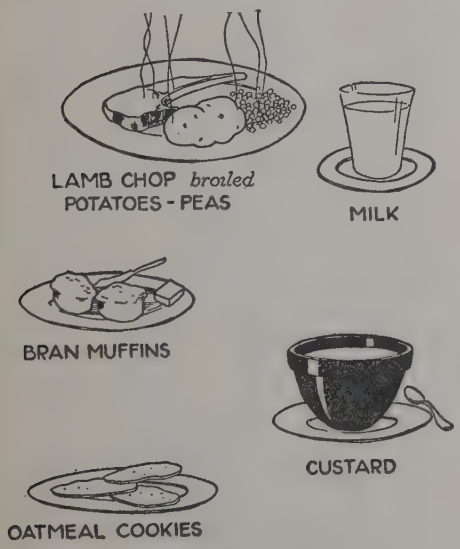
There is much talk about the use of meat and perhaps it will be well to say that the people who have done the most toward the advancement of civilization have been the meat and vegetable eating people and not the vegetarians. Although the proteins can be obtained from vegetables, there seems to be something else which meat alone can give. The fault then is not in eating meat at all but in eating it too often and in too great quantities. One needs more meat in winter than in summer. English and American people eat too much meat. A proper amount of meat makes one active, while too much makes one nervous. People who do manual work can without affecting the nerves eat more meat than can students or people engaged in less active labor.

We have seen that starch is important and that before the tissues can use it, it must become sugar. Why do people often say we should not eat sugar or candy? Perhaps it will help us to find out if we remember how many of the foods we eat contain starch, which will, of course, make sugar. We should also remember that sugar is not a muscle-making but a heat-making food. Sugar and candy are nourishing, but if we eat much of them we add too much sugar to our diet and make our stomachs liable to fermentation.

Then again, such things would do little if any harm to the average person if eaten at the end of a meal. But they are seldom taken then and one of the most injurious things we can do is to eat at irregular hours. Why? Because, if we are regular in our meal times, the digestive juices become regular in the time that they appear in the stomach

and intestines, and at the usual time for eating they will flow freely to do their work. If between the meals we take any kind of food, it stimulates the juices to flow and then when we need them for the regular meal, they do not flow readily and the food is not so well digested.

Certain people tell us to eat no breakfast, others to eat no lunch and still others to eat nothing just before sleeping. None of these things touch upon the fundamental rule of eating, which is: Eat only so much as is needed for nourishment and eat only at regular hours.



A CHILD'S DINNER

A model dinner for a growing child. (From Baldwin's *Nutrition and Health.*)

One of the most frequent causes of overeating is the practice of serving too many things at one meal. In order to eat a little of each thing present too much is eaten. When many things are served at one meal the possible number of things is much sooner used up and one becomes tired of his food, or, as we say, he loses his appetite. There is also the added expense in money and time.

Rich pies, cakes and puddings you may think are useful because they contain sugar, eggs, milk, fat and flour. All of these ingredients are nourishing, but unfortunately they are often so put together as to make the products very hard to digest.

The main thought in the hygiene of digestion is: Eat those things which are for the bodily good, although they may not be the most pleasing to the taste. Avoid those things which do harm, although they may be most to the liking. EAT TO LIVE BUT DO NOT LIVE TO EAT.

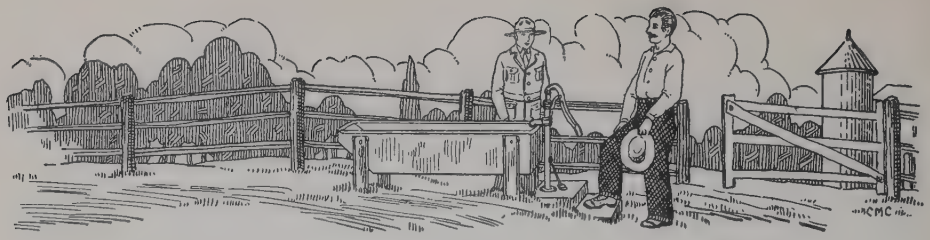
THE HYGIENE OF DIGESTION—WATER

In the little corn plant that grows from the seed because of the warmth and moisture we found nine parts out of ten by weight were water. In all plants, from the least to the greatest, we find a large quantity of water. Water is the natural drink for all of us. It exists in the greatest abundance.

The purest water is taken from nature's reservoirs where they are not near large cities. When the city's refuse (sewage) empties into a body of water it leaves many impurities and the germs of disease. The water must then be taken from beyond the reach of the impurity or it must be boiled to kill the germs. Rain water is the purest form of water aside from those just mentioned, provided it has not become impure after falling.

Sugar and salt must have water to dissolve and dilute them before they can be absorbed by the body, hence the desire for drink after eating them.

All processes of digestion require water to complete them. It is, however, not a good practice to wash food down with water. Let the saliva moisten the food and let the water be taken a little at a time, when the mouth is empty.



THE HEART MAY BE COMPARED TO A PUMP

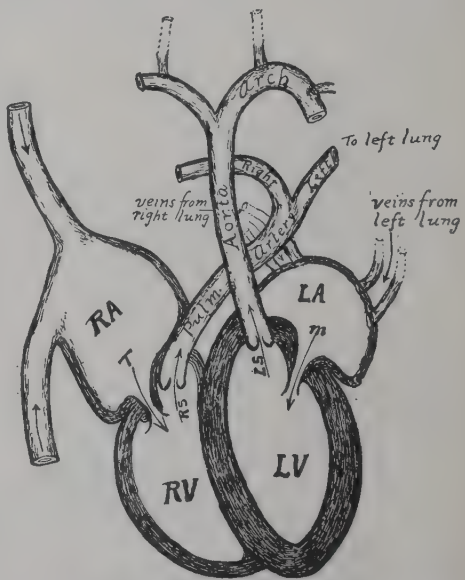
CIRCULATION

WE HAVE likened the body to a house because of the way it is built, and we have compared it with a community because it is made up of a large number of living things (cells), each one of these cells or groups of cells (tissues) making its contribution to the community life by doing some one particular kind of work for the community.

We have followed the food along the digestive canal; we have watched the steps of its preparation to make it soluble, so that it might be easily absorbed into the blood and lymph tubes.

You have probably already guessed that every living, active cell, tissue and organ in the body (community) has an interest in the absorbed food. Even the cells that line the mouth, stomach and intestines through which the digesting food was passing took practically nothing for themselves as the supply was passing.

The entire carefully prepared supply was finally drawn into the common supply stock to be distributed to every active cell of the body. The muscle cells in the arm that reached for the food, and even those in the legs that brought you to the table, and the nerve cells that carried messages to the brain and to the organs all earned an interest in that common supply of food. If any of these cells or tissues or organs were to fail to get its necessary supply of building material and fuel it would die of starvation, and that might destroy the life of the whole community.



HOW THE HEART WORKS

The heart has two receiving and two sending chambers. Blood comes to the heart through the two great veins that empty into the right auricle (RA); thence through the tricuspid (meaning "having three points") valve (T) into the right ventricle; thence through the right semilunar (meaning "half-moon shaped") valve (RS) into the pulmonary artery which carries it to the lungs where it is purified. The blood comes back from the lungs and empties into the left auricle (LA); thence through the mitral (resembling a miter) valve (m) into the left ventricle (LV) thence through the left semilunar valve (LS) into the aorta, from which branches distribute it all over the body, from which it returns to the right auricle, having thus completed one turn of the circulation.

CHANNELS OF DISTRIBUTION

But how is this distribution brought about? Through a system of tubes and a central pumping station, which we

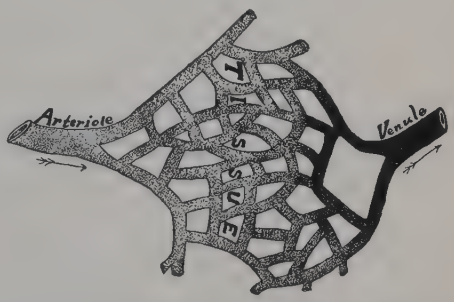
call the *circulation system.* The central pump we call the *heart.* The large tubes which carry the blood (in which the prepared food is mixed) away from the heart we call the *arteries.* The large tubes which carry the blood back to the central pump we call the *veins.* The arteries, like the trunk of a tree, divide into smaller and smaller branches. The very small twigs or branches that we find in every organ we call *arterioles.* These arterioles, not thicker than a common sewing needle, break off into tiny branches, not thicker than one of the hairs of your head, and because they are hair-like branches we call them *capillaries.* These tiny capillaries carry nourishment (building material and fuel) to every active, working cell in the body.

Having pictured in your imagination just how the food is distributed, you will wonder how the blood gets back to the heart again. The capillaries do not have open ends from which the blood pours. They have very, very thin walls, as thin as tissue paper—yes, thinner. Through these thin walls the food part of the blood—the clear yellowish *plasma*—oozes slowly, but there is enough of it to supply every cell with all it needs. The larger part of the blood does not ooze or seep through the thin capillary wall, but empties into tiny *venules,* or very small veins, from neighboring capillaries. These venules come together to make little veins and these come together as tributaries to make larger veins. Finally these larger veins combine and flow together to make the great vein trunks that empty into the heart.

On some of your hikes you have seen how rills flowing from springs run together to make a brook and brooks combine as tributaries to make a river. In a similar way blood comes back to the heart from the millions of capillaries. Two great veins, one from the upper part of the body and one from the lower, empty blood into the right side of the heart.

Course of distribution

As the blood goes slowly through the capillaries some plasma oozes out to supply the nearby cells; but all the red cells that are floating in the blood and most of the plasma also pass on through the capillary into a venule, thence into a small vein, then into a large vein and finally empty back into the heart by one of the two very large veins. In this way the blood circulates, coming back to the heart every few minutes.



CAPILLARY CIRCULATION IN THE TISSUES
After much subdividing, arteries become tiny arterioles which reach the tissues carrying food and oxygen. The arteriole branches into minute capillaries which carry little streams of bright-colored blood very slowly between the tissue cells. As the blood oozes slowly through the cells, they take from the blood the needed food and oxygen. The blood, in turn, takes carbon dioxide from the tissue cells. This makes the blood in the venules ("little veins") look dark.

The boy scout and mr. brown's pump

Now you will want to know all about the pump. On one of your hikes to the farm, you may have stopped at the pump in the yard for a cup of water. You lifted the handle of the pump and then forced the handle down, repeating this with regular strokes. You remember that with each forceful down stroke of the pump handle the water flowed out of the pump spout in a full stream, while only a small stream flowed as you lifted the handle.

The pump handle acts as a lever and when you lifted the handle, the other (short) end of the lever was lowered. The short end had fastened to it a rod that plunged down the inside of the pipe six or eight inches; the lower end of the rod or plunger evidently got hold of something; it caught the water, and as you forced the handle downward the water was lifted. If you had never seen the parts of a pump, you might have asked the farmer, "Mr. Brown, please tell me what takes hold of the water so you can lift it by pushing the pump handle down?"

"Why, Boy Scout, didn't you ever see the inside of a pump?"

"No, Mr. Brown."

"Well, you see, the plunger has a valve that can open when the plunger is forced down through the round tube or cylinder; then as you start to lift the plunger the valve closes and is held tight just by the weight of the water, and because the plunger valve fits the cylinder quite closely, the lifting of the plunger lifts the whole column of water which fills the pipe, and the rising column of water flows out of the spout so long as the plunger is rising. Understand?"

"Sure! and thank you very much, Mr. Brown. Would it help you if I pumped some water into your watering trough?"

"Well, it certainly would if you would like to do it."

"Here goes! delighted!"

Now that you understand about the water pump it will be easy to understand the way the heart does its work.

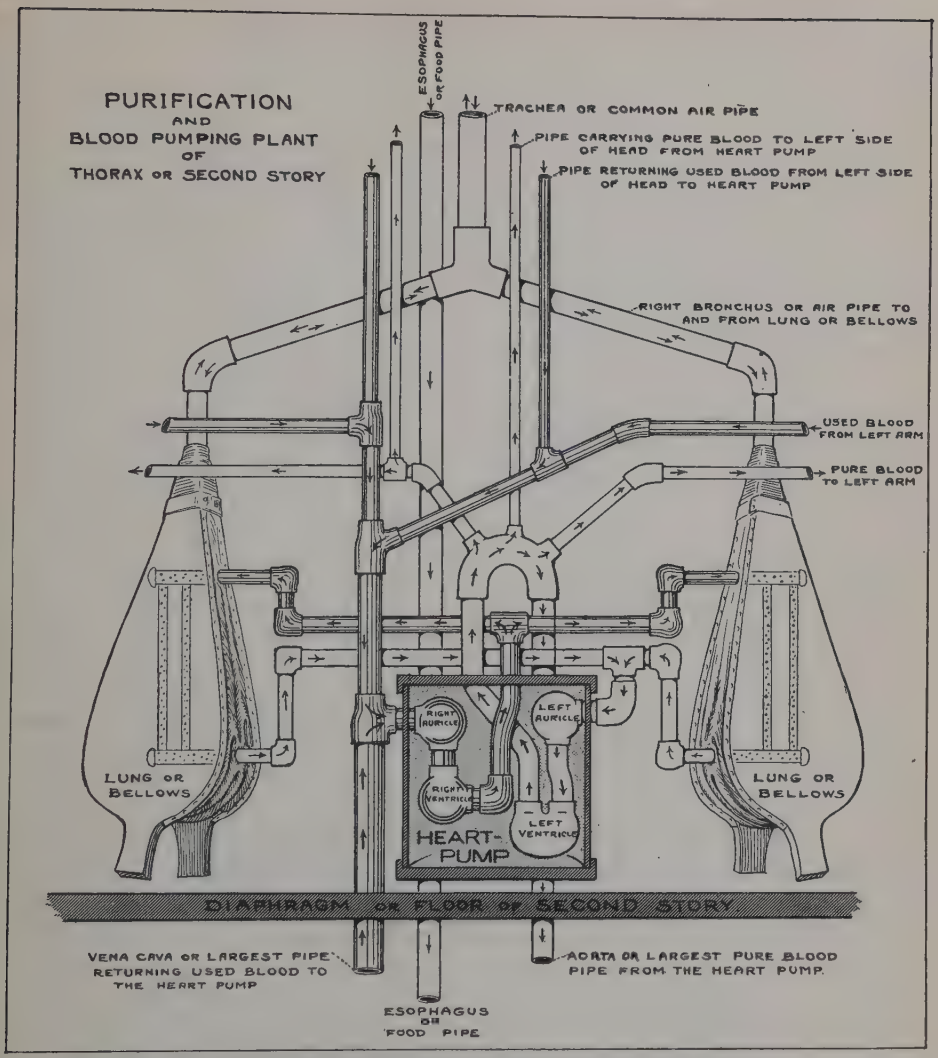
Why the heart is like a pump

The heart is a force pump and like the water pump really has two valves for each pumping chamber. It may be that Mr. Brown explained that, as you lift the plunger and the column of water above it, you also lift the column of water below the plunger. There is a check valve at the lower end of the plunger chamber. This valve opens upward and lets the lower column of water rise to fill the chamber behind the plunger valve as that is lifted. When the plunger has finished its upward stroke the check valve instantly closes and so holds the chamberful of water. Every force pump must have two valves.

Now you understand why the heart or any pumping chamber must have two valves. The heart has two pumping chambers which lie side by side as shown on Page 326. The left chamber is called the left *ventricle.* The right chamber is called the right *ventricle.*

Note that the valves of both chambers are at the upper end of the ventricle. Look first at the left ventricle. Notice *m,* the entrance valve of that chamber; LS is the exit valve. When the left ventricle expands the blood flows rapidly and easily through *m,* but none can come back through LS, as these valves open upward toward the artery only, and not downward and so, as the ventricle relaxes and expands, the blood from the full left auricle, LA, flows easily and rapidly through valve *m,* thus very quickly—instantly—filling the left ventricle LV. Then this chamber contracts very strongly and the blood that filled it is forced out, not through *m,* as that valve closes when there is pressure from below, but through the valve LS, which opens as soon as the contraction of the strong walls of the ventricle makes the pressure in the ventricle higher or stronger than the pressure in the big artery, the *aorta.*

In a similar way, opening or relaxing of the right chamber, RV, lets the blood rush through valve T, while closing or contracting of the right ventricle forces the blood up, closes valve


PURIFICATION
AND
BLOOD PUMPING PLANT
OF
THORAX OR SECOND STORY
ESOPHAGUS OR FOOD PIPE
TRACHEA OR COMMON AIR PIPE
PIPE CARRYING PURE BLOOD TO LEFT SIDE OF HEAD FROM HEART PUMP
PIPE RETURNING USED BLOOD FROM LEFT SIDE OF HEAD TO HEART PUMP
RIGHT BRONCHUS OR AIR PIPE TO AND FROM LUNG OR BELLOWS
USED BLOOD FROM LEFT ARM
PURE BLOOD TO LEFT ARM
RIGHT AURICLE
LEFT AURICLE
RIGHT VENTRICLE
LEFT VENTRICLE
HEART-PUMP
LUNG OR BELLOWS
LUNG OR BELLOWS
DIAPHRAGM OR FLOOR OF SECOND STORY
VENA CAVA OR LARGEST PIPE RETURNING USED BLOOD TO THE HEART PUMP
AORTA OR LARGEST PURE BLOOD PIPE FROM THE HEART PUMP
ESOPHAGUS OR FOOD PIPE

THE PUMPING PLANT IN THE HUMAN HOUSE

Here the artist has shown how the heart is like a pump and the lungs are like a bellows. Starting at the Heart-Pump trace the course of the blood through the pumping system. The unshaded pipes contain pure blood and the shaded ones contain used, or impure, blood. The esophagus, or food pipe, is shown; but it is not a part of the purification and blood pumping plant of the human house.

T and opens valve RS and the blood rushes out through the *pulmonary* or lung artery.

How the Heart Works

Both chambers or ventricles contract at the same time, so at the same moment the two great arteries (aorta for the general body and pulmonary artery for the lungs) receive a gush or rush of blood from the heart.

By this time you will be wondering why there are two pumping chambers in the central pumping station. Think a moment. The blood is brought to the heart through the two large veins, one coming from the head and shoulders and one from the part of the body that

is below the heart. These large veins bring back to the heart blood which has been distributed to the organs, tissues and cells. The living, hungry cells take food out of the blood plasma and receive oxygen from the oxygen carriers—the red cells of the blood.

The blood was further changed by the addition of various waste substances that the cells could not use, and that would injure the cells if they were not removed. The blood that comes back from an organ through its vein is thus much changed from that which was distributed through the arteries. This we call "impure" blood. The most noticeable impurity in it is the carbon dioxide which is being carried by the red cells (*red corpuscles*) of the blood. It is very important that this carbon dioxide which the blood has brought from the organs be got rid of as soon as possible, so the right ventricle of the heart, by contracting, sends this dark, purplish, impure blood through the pulmonary artery to the lungs where it gives up its carbon dioxide, receives oxygen and comes back to the left *auricle* bright scarlet, "pure" blood.

Passing from the left auricle through valve *m* into the left ventricle it is sent out through the aorta to be distributed by the branching arteries to all the organs and tissues of the body, presently returning to the right auricle again as impure blood, thus having completed the circuit, or having made a complete turn of the double circulation.

What the pulse tells us

You have read Mr. Brown's explanation of the pump. You remember that the water left the pump spout in gushes, one gush with each lifting of the plunger, that is, with each emptying of the pump chamber into the pipe and through the spout.

In a similar way the blood passes through the arteries, not in a smooth, even flow, but in a throbbing, pulsing stream. If an artery were cut so that the blood could pour out, the stream would issue in gushes just as did the water from the pump.

Do you know where to find your "pulse" on the wrist? But you have the pulsing not just at the wrist alone; wherever an artery comes near to the surface its pulsing may be felt. See if you can find the pulsing of an artery just in front of the opening of the ear. The same artery can be felt throbbing a little higher up and farther forward where it crosses the temple. Can you feel the arteries deep in the neck and beside the windpipe? Can you feel an artery on the top of the foot? The reason why we cannot find many places where the pulse may be felt is because the arteries lie deep in the tissues, protected by muscles and bones.

Count the pulse at the wrist. How many beats in a minute? Did you say 72? That means that the heart contracts or beats that many times every minute, and that many gushes or waves of blood rush along the arteries to the tissues in every minute.

Now go quietly to your room, or better, to a couch in the room where you are now sitting. Lie down quietly and remain still for at least five minutes, breathing slowly and regularly. Then count your pulse. "Only 68 a minute," you say. Now go out and run around the house twice, or to the corner and back; then at once count your pulse through one minute or at least a half minute. At what rate per minute was it going after your run? Did you say 90? Would the results be the same for all the boys of a patrol? No. Out of the eight there might be no two whose pulses would be the same at the first counting, or which would respond to the other experiments in

just the same way. But the rate of beat would always be slower when lying down quietly than when sitting up. What is the average pulse rate for the eight boys? What is the average after the minute of sprinting? Notice that with every boy the rate is much increased by the sprinting, but it is not the same rate and the increase is not in the same proportion.

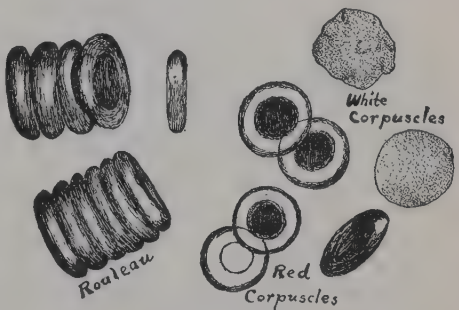
Any thoughtful youth can figure out why the heart should pump faster during brisk exercise. The tissues need more food and fuel and more oxygen, and they need also to be rid more promptly of the waste materials that accumulate when the cells are working harder. The pump must work harder to make the blood circulate faster.

THE LYMPH AND ITS CIRCULATION

There is another matter that you may have been wondering about. What became of the plasma that oozed out through the capillary walls to nourish the working cells? This escaped plasma is not all used up by the cells. In fact, only a small part of its bulk is consumed, and besides there is added to it waste matter which the cells throw out that just about makes up for what they took out of the plasma. So the change in the plasma that oozes out of the capillaries is not so much a change in amount as in quality. The plasma comes to the cells rich in food and pure but it flows away poor in food and impure, because of waste materials added to it.

But how does it get away from the tissues where it left the capillaries? The plasma oozes not only through the capillary wall into the spaces between the cells, but slowly along these spaces until presently there is a rather direct space or channel lined with thin cells, like those that made the wall of a capillary. This channel we call a lymph radicle, or little root, and the plasma—the changed plasma—we now call *lymph*.

Lymph radicles combine to make larger channels called *lymphatics*, and these form tributaries to a large lymph trunk or vessel that flows from the abdomen up through the thorax and not very far from the heart it empties into one of the great veins that is about to empty into the heart. So, you see, the escaped plasma comes back as lymph.



CORPUSCLES

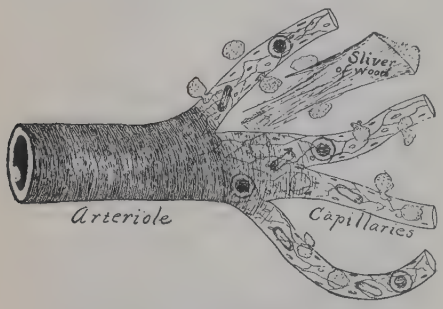
The white cells (leucocytes) are typical cells and much like the amoeba. The red cells are so specialized for their work that we can not call them typical cells—we call them red corpuscles. They gather into rouleaus ("little rolls") if the blood collects in a large vessel and does not flow rapidly. The red corpuscles are oxygen carriers.

In the intestines, where food is being absorbed, the oil, in very fine white emulsion, is poured by the absorbing cells into lymph radicles which in turn pour it into larger lymphatics. The emulsion is white like milk, and the thin-walled lymphatics of the intestinal region look white, so we call them *lacteals*, but the lacteals are only emulsion-carrying lymphatics; and the milky *chyle*, as it is called, is poured into the blood of the veins above the heart as we have already described.

THE LIFE FLUID—THE BLOOD

We have not said much about what circulates in the distribution system, but what has been said must make it clear that the circulating fluid is blood. You know that the blood of animals that have a backbone is red. What

makes it red? There is no red stain or dye in the blood. Its red color is due to millions upon millions of tiny red cells or corpuscles. There are so many and they are so close together that they give the blood its red color. They float in a clear, yellowish fluid which has been referred to before as the plasma. The dissolved (digested and absorbed) food is in the plasma.



WHITE CORPUSCLES

When a sliver pierces the skin, the white corpuscles seem to be attracted to the point of injury. They work their way through the tiny pores without breaking the delicate capillary walls, encircle the sliver, and thus protect the surrounding tissue. But the "soldiers" of the "army of the defense"—the white corpuscles—lose their own lives and finally end as pus cells when the sliver festers out or is drawn out.

Besides the red corpuscles, which are not typical cells, since they have been changed for their special work, to be described later, there are the so-called "white corpuscles" or *leucocytes*. These are typical cells, similar to the amoeba, and they perform very important and wonderful work. Because they are really protoplasm, they can change shape and move. They can squirm through tiny pores or holes in a capillary wall, holes so small that red corpuscles could not possibly get through.

Some of the leucocytes go out among the working cells as scouts. If they find anything wrong or any damage being done in the tissues as by a sliver, tear, bruise or break, these leucocytes set about to repair the damage done. They are like a standing army, a police department and a health department. In many cases they sacrifice their own lives to repair a damage done to the tissues. In this they are also similar to the army or to a police force.

Why does one not bleed to death when an artery or vein is cut? Of course, there may be that danger, but most wounds bleed only a little and stop. How is this brought about?

As soon as a cut begins to bleed the blood begins to thicken or clot in the wound; and if there has been no very large artery cut, the clot will plug the wound and stop the bleeding. The clot is composed of fibers that form in the blood that flows from any break in the walls of a blood vessel.

Control of the Circulation

As you would naturally expect, the circulation is controlled by our engineer who is installed in the tower. However, the engineer does not have to command each beat, any more than he has to command the stomach to start making gastric juice to digest the milk, egg or meat.

In the first place, the heart itself, the muscle tissue, seems to have from nature the habit of following each beat with another. So the central controlling engineer does not tell the heart to beat—it beats naturally—but the rate of the heartbeat is controlled by the nervous system. Nerves from the autonomic (self-governing) nervous system send "Hurry up" messages to the heart, whenever the general conditions require that the circulation be hurried. If the heart beats too rapidly, a nerve from the brain brings a "Slow down" message that slows and controls the heart beats in a way similar to a driver's control of a horse with the reins.

How the Blood Is Sent Where Needed

After one has eaten a meal, the stomach and the rest of the digestive canal need more blood, so the auto-

nomic nervous system sends out messages to the muscles in the walls of the small arteries and arterioles of the digestive organs. These muscles relax and the arteries get larger and let through more blood, so the digestive organs secure much more blood than they have between meals when they are resting and the muscles or brain is working. Now you can understand why one should not try to do hard muscular work or active brain work soon after a meal. After the digestive system has nearly finished its task, one may then begin strenuous muscular work. The muscles are commanded and begin their work. They soon need more fuel, so the small arteries that supply the muscles obey a message from the internal self-governing nervous system. They expand and a greatly increased supply of blood rushes to the working muscles, while less goes to the rest of the body.

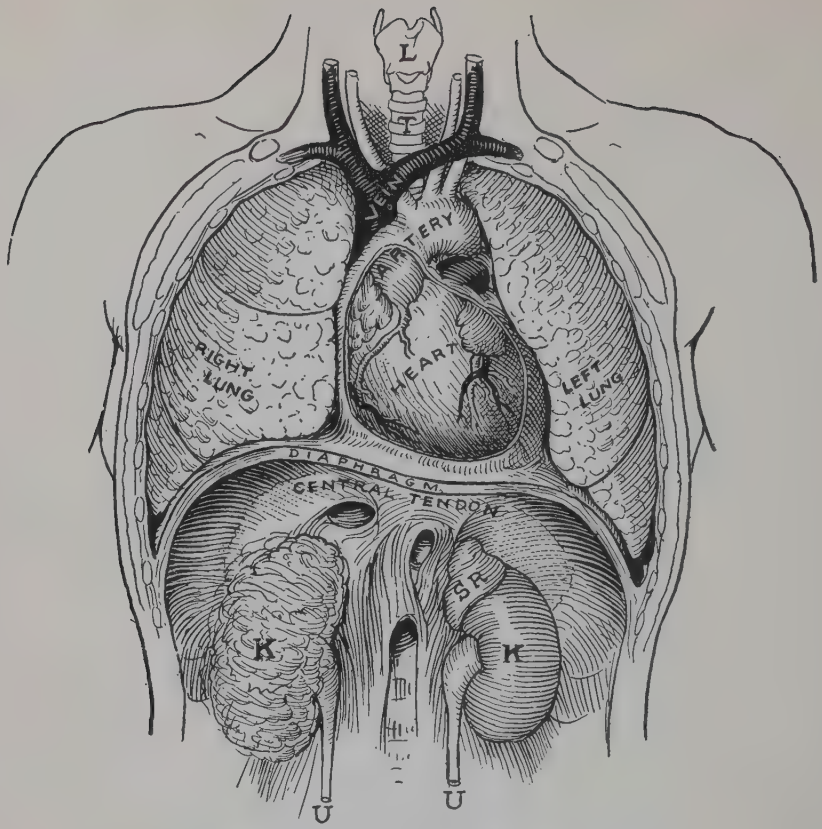
When one begins to study he sits quietly and thinks. The digestive system does not need much blood, nor do the muscles, but the brain needs a great deal. The same part of the nervous system that controlled the blood supply to the muscles now acts, causing the small arteries in the brain to swell, and the needed blood supply is quickly sent to the brain.

While the distribution of the blood is controlled by the nervous system, it is automatic and reflex and one does not need to think out what his heart and arteries must do. However, knowing what you now do, you can decide that more blood should go to your muscles to develop them. You exercise vigorously, knowing what will happen in the circulation. Thus one has a measure of voluntary control over his circulation.

Some functions of the blood

The blood never rests. Night and day it is on its round of duties. It starts out rather briskly, impelled by the force of the heart and runs through the arteries at the rate of twelve to fifteen inches per second. But in the capillaries it goes no faster than one-fortieth of an inch a second, for here it is that the real work of housecleaning is done, and the blood is obliged to go more slowly to perform its functions thoroughly. When it gets to the veins, it finds the little gates or valves that close behind it and prevent it from going back. The action of the lungs in breathing gives the blood a new impulse and thus it proceeds on its way through the veins to the heart.

The blood has several well-defined functions. It carries food and waste. It receives the food from the alimentary canal and takes it away to places of storage or to tissues where it is to be oxidized. It collects waste from the active tissues and carries it to the organs of excretion, especially to the lungs and kidneys, through which it is taken away from the body. The lungs have a two-fold function, since the blood in passing through them not only gets rid of the chief oxidized waste product of the body—carbon dioxide—but accumulates oxygen in its stead. One service which the circulating blood renders the human house is often ignored—the distribution of heat. The active tissues—those in which oxidation is taking place rapidly—warm the blood in passing through them. This giving of heat to the blood limits the rise of temperature in such tissues and the blood transmits some of the heat to less active regions of the body. It also carries heat to the surfaces of the skin and the breathing apparatus.



CHEST, SHOWING ORGANS OF BREATHING (HALL)

Notice the larynx (L) and trachea (T) and the two lungs, which fill the thorax. Between the lungs is the heart with its apex turned toward the left.

Just below the lungs and heart is the muscular partition (diaphragm) between thorax and abdomen. It is arched upward into the chest. A contraction of the muscle fibers, which radiate out from the white central tendon, flattens the dome-like diaphragm and thus expands the lungs, but compresses the organs in the abdomen.

The kidneys (K), organs of excretion, lie next to the back wall of the abdomen. Each lies in a bed of fat (one is shown with fat removed); each has a tube (ureter) (U), and above each is a suprarenal gland (SR).

RESPIRATION

WE DO not need to take a walk today to get subjects to talk about. A mental hike through our memories should be enough. You remember the amoeba, the little protoplasmic animal, so small it can drop through the eye of a needle and so active and changeable in shape that it can squirm through a tiny hole a tenth the size of a needle's eye. You remember also that the amoeba can do many of the things other animals do, move, reach out for food and digest food. It is sensitive to heat and cold, to moisture and light. It needs not only food but oxygen as well, and it throws out waste and any undigested matter that it takes with its food. Finally, it reproduces its kind. The mother amoeba produces twin daughters.

The amoeba's breathing is very simple, as are all of its actions. It simply absorbs oxygen from the water

in which it floats or crawls, and it throws out the carbon dioxide which is a waste always resulting from the use of oxygen by any living cell.

In a general way we breathe as the amoeba does. We take in oxygen and throw out carbon dioxide, and we do it for the very same reason that the amoeba does—to get the energy which our food contains. It is that energy that we use when we walk or talk or think.

The fireman feeds his engine fuel and opens the drafts so that the oxygen can be drawn into the fire and unite with the carbon of the fuel, burning it to produce energy: heat, light and motion. The combined carbon and oxygen (carbon dioxide) is drawn away from the fire and escapes up the flue with the smoke.

In a similar way we breathe in oxygen, which, in the active cells all over the body, combines with carbon forming carbon dioxide and releasing the energy of motion and heat. This process, going on all the time in one's body, furnishes the life energy. When the process stops the body stops moving and gets cold and dies. So breathing (*respiration*) is the first necessity of life. You can live forty days without food, but you cannot live ten minutes without oxygen.

The process of getting oxygen to the active cells of our bodies is rather complicated. You see there are millions and millions of cells that are shut off from direct contact with the air. How can the muscle cells in your biceps, or the nerve cells in your brain get the oxygen they must have if they are to go on moving or thinking?

The second story (thorax) of your house contains your breathing and ventilating apparatus, or lungs. Fresh air is drawn into the lungs where it comes into very close contact with the blood, there being only an air sac wall and a capillary wall between the air and the blood. These walls are thin and moist. Oxygen, which makes up about one-fifth of the air we inhale, is easily and rapidly absorbed by these moist tissues, and so comes quickly into direct contact with the blood.

The blood, as you know, contains great numbers of red corpuscles whose work is to carry oxygen which is absorbed through the walls of the air sacs. The blood that flows through the lungs is carried to the lungs by the large artery (pulmonary artery) from the right chamber of the heart. This blood that comes into the right-hand pumping chamber comes from all over the body—from arms, head, legs, abdomen. It is the used blood that comes back from the active tissues impure, having given up its oxygen to the cells, tissues and organs along the way. It is loaded with carbon dioxide and other impurities or waste.

The blood is purified, so far as the carbon dioxide is concerned, in its course through the lungs and is brought back pure to the left auricle where it passes down through the valve as soon as the left ventricle relaxes and opens.

When this chamber of the pump contracts, the pure blood is sent out through the aorta to be distributed all over the body, each red corpuscle carrying its precious load of oxygen to some working cell. This is the process of breathing. This is the way the house you live in is ventilated.

The Ventilating Passages and Chambers and How They Operate

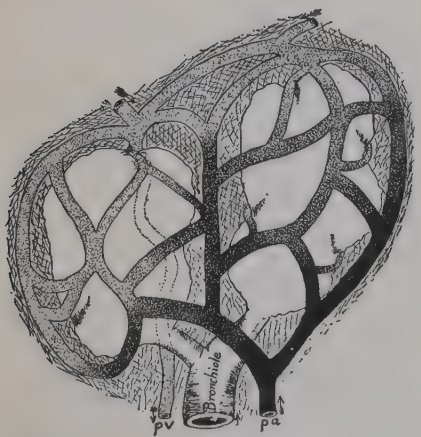
The lungs that nearly fill the chest (thorax) are not just two big hollow sacs. They are made up of millions of tiny air sacs. The wind pipe that you can feel on the front of your throat branches, in the upper part of the chest, into two large parts as the drawing shows, and these divide and subdivide and each smallest branch has

at its end an air sac. The air drawn into the lungs makes its way into these little air sacs where it comes in contact with the blood as has been described.

How air is drawn into the lungs

You will wonder just what does the work of drawing in the air. The lungs do not push the chest walls out, but the chest walls rise, the chest increases in all of its dimensions really, and the lungs are pulled open, reminding one of the blacksmith's bellows. When the lungs thus open, air is drawn in to fill them. It is drawn in through the nose and the windpipe.

Stand with bare chest before your mirror as you are preparing for bed, or upon arising. Watch your chest as you take a number of full breaths. You will notice that the walls not only rise but that they move out, increasing the chest dimensions not only vertically (up and down) but also from side to side.

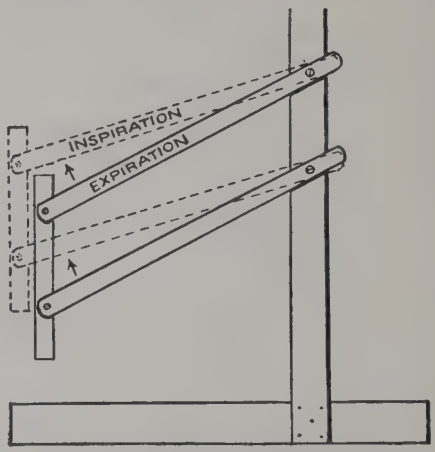


AIR SACS WITH CAPILLARY NETWORK (HALL)

A bronchiole dividing and ending in two air sacs. Surrounding the sacs (alveoli) is a network of capillaries.

The blood, deep crimson in color, comes bringing its load of carbon dioxide. The pulmonary arteriole (pa) branches into many capillaries. As these thin-walled capillaries pass over the very thin walls of an air sac the oxygen in the air sac goes through the two thin walls and is taken up by the red corpuscles. They give up their carbon dioxide in exchange for the oxygen and in doing so change in color from deep crimson to bright scarlet, thus changing the appearance of the blood vessels from bluish to red. The pure, oxygenated blood flows back to the left auricle of the heart through a branch of a pulmonary vein (pv).

You can figure out just how the chest wall is pushed forward if you study the drawing. When the muscles of the chest are relaxed the *ribs* slant diagonally downward as shown. When



A LESSON ABOUT BREATHING

Do the lungs push the ribs forward or do the ribs move forward and pull the lungs open? As shown in this diagram, the ribs are lifted (by the chest muscles) and push the chest forward. This increases the space within the chest. Air rushes in, through the air passages, and fills the lungs.

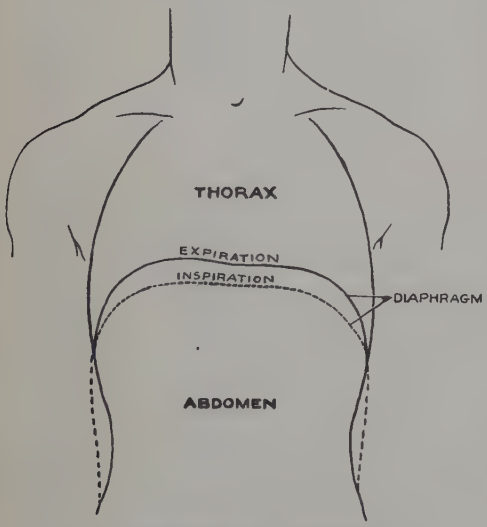
the chest muscles contract the ribs are pulled up. When they rise the breastbone, the *sternum*, is pushed forward, thus increasing the depth of the chest space. The lifting of the ribs by the chest muscles increases the front-back diameter of the chest. It also increases the side-to-side diameter.

As you watch your body walls moving while you breathe deeply, you notice that the abdomen also gets larger. Why? There is a muscular partition between the thorax and abdomen. This partition, or *diaphragm*, arches strongly upward into the chest cavity. Thus the floor of the thorax is a dome-shaped muscle. When one breathes in (inhales or inspires) the muscles of the diaphragm contract. This flattens the dome, pushes the stomach and liver and intestines farther down in the abdomen, thus pushing out the walls of the abdomen as

you noticed. But this flattening of the dome of the diaphragm, like pulling open a bellows, opens the lungs and draws air into them.

It must be clear to any boy or girl that this inhaling act is done really by muscles. The lungs are not active in the process; their work is different (exchanging carbon dioxide for oxygen) and has already been described.

If breathing is done by muscles you should be able to control it. To a considerable extent you can. You can take deep breaths or shallow ones; you



DIAPHRAGM ACTION

The diaphragm arches into the chest muscular contraction pulls the dome down to the position indicated by the dotted line (INSPIRATION), thus lengthening the chest cavity from above downward. This action draws air into the lungs just as air is drawn in by a bellows.

can breathe rapidly or slowly; you can even stop breathing altogether for a short time, but after a minute or two or three the cells and tissues of your body call to the brain so strongly for their necessary oxygen that the brain orders the breathing to begin again.

Breathing is automatic and reflex just as the heart action is. How fortunate that is! It goes on when one is asleep or giving his attention to some other matter.

On the other hand, it is fortunate that one can change his rate and depth of breathing, for, by purposely breathing deeply, one can establish a habit that develops the whole ventilating system.

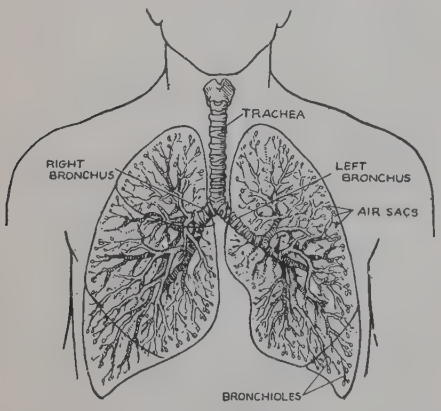
Air is drawn into the lungs through the nose. Examine the nose by looking into a mirror. You and your chum might examine each other's noses. Notice that the passages that open at the nostrils are not wide open, but are reduced by a bulge. Perhaps you can see two bulges—the *turbinated* bones. The entrance to the nostrils also has little hairs growing out into the air passage. If the air is cold, it gets warm as it winds around the narrow, crooked passage; if it is dry it takes up moisture from the moist hairs and membranes; if there is dust in the air most of this, perhaps all of it, will be caught on the moist surfaces and kept from the lungs. In this way the air is prepared for the delicate, sensitive linings of the inner air passages.

In the upper part of the nose there is a sort of little side channel into which one can draw the air by sniffing. This is the smelling channel. A little air goes through the smelling channel at each breath. When a man or a dog or any of the animals that has an acute sense of smell in the nose sniffs, an unusual amount of air is drawn into this upper smelling channel and can be tested by the smell sense. How important that is! It is nature's provision to protect one from breathing foul and polluted air. Of course, the hunting dog uses his keen sense of smell to track his prey. But most animals use their sense of smell to protect themselves either from some enemy whose approach they may detect by smell or from bad air or food which they test by smell. We protect ourselves from both bad air and bad food by our sense of smell.

To keep well, make sure that you have pure, fresh air and plenty of it. Pure air is free from dust and bad odors. Dry air may be pure, but pure moist air is better than pure dry air. Very cold air may be free from dust and pure, but if one breathes fast in zero weather the air will probably not get warmed up by the time it reaches the lungs. Very cold air is always very dry and if it is cold and dry it irritates the delicate lining of the air passages. If you are skating or coasting in zero weather have a knit or crocheted thick muffler of wool over the nose and mouth. Breathing through this covering warms and moistens the air and yet leaves it pure and fresh.

The Voice

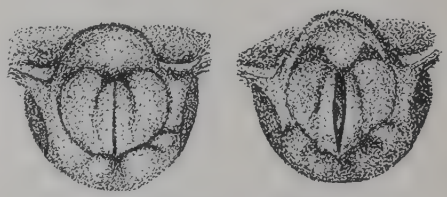
Mammals and birds all have voices. The voice is a noise or tone made by the air as it passes out of the windpipe. At the upper end of the windpipe is a voice-box (*larynx*). Feel your own larynx. The front of it projects to make what people call the "Adam's apple." The apple that Eve gave Adam in the garden is said to have stuck in his throat and left a lump that sons of Adam have inherited. Of course, that isn't really true but it is one of the old legends.



THE AIR PASSAGES

This diagram shows the trachea branching into the two bronchi, and these in turn dividing into hundreds of bronchioles. At the end of each bronchiole is a tiny air sac or a pair of air sacs.

The Adam's apple is the place where the voice strings (*vocal cords*) grow and develop. When one inhales, the cords are held apart so that the air flows in easily; but when one exhales, the cords may be brought close together, if one wishes to make a sound. When they are brought close together they vibrate and make a tone. Say *ah, oh,* or any of the vowel sounds: *a, e, i, o, u.* If you put your lips together before you give the tone you can change the sound to *pa, pe, pi, po, pu; ba, be, bi, bo, bu; ma, me, mi, mo, mu.* If you put your tongue against the roof of your mouth just behind the teeth you may say *ta, te, ti, to, tu,* or *da, de, di, do, du;* or if you put the middle of your tongue against the back part of the roof of your mouth you can say *ga, ge, gi, go, gu.* Or we may have a vowel sound first, followed by the consonant sound, as *ap, ep, ip, op, up,* and so on through the consonants given above. In this way voice is spoken into words and words have a meaning. We express our thoughts in words. We may express our emotions and poetic thoughts in song.



THE VOCAL CORDS

This is the way the vocal cords appear as seen from above, looking down into the larynx. At the left the opening (glottis) is closed, as it appears when one is lifting a heavy weight with his hands. At the right the cords are separated just enough to be thrown into vibration by air that passes out of the lungs. As the cords vibrate they produce the voice. In ordinary breathing the glottis is open wide so the air can flow through.

One can make a tone like *oh* or any clear vowel tone high pitched or low pitched, as he wishes. If one decides to pitch a tone high, the brain

sends a message to the larynx, the cords come very close together and are pulled tight. Then the tone is high in pitch. If the cords are loosened and separated a little the tone drops to one of lower pitch. By practice one can control the pitch perfectly.

If one observes the different kinds of breathing and voice he can list the following: laughing, crying, sobbing, sighing and singing. Most of these changes of the voice and breathing express emotions and even a little baby can do any of these things except singing—but the cooing of a baby is perhaps its own way of singing.

EXCRETION

GO TO the kitchen just after dinner. Look for garbage and waste material that has to be burned or thrown away. In the garbage pail there are potato parings, apple peelings and cores, banana skins, tea leaves and celery tops. All of these things in the garbage pail come from the grocery as a part of the food material. But these seeds and skins and tops are not digestible and have to be thrown away as waste matter.

Besides this indigestible waste in the garbage can, there is another kind of waste material leaving the house in pipes. In the bathroom, the kitchen and the laundry there is water in which we have washed our bodies or our dishes or our clothing. It is dirty water, full of waste matter and it pours into the system of pipes that we call the sewer system. The main pipe which leads away from the house empties the sewage into one of the city sewers to be carried away.

In a similar way, the personal house one lives in, the body, has a garbage and sewer system for getting rid of unusable or used-up waste matter. We take with our food a considerable amount of material that our digestive organs cannot digest—cellulose, gristle, and other things. This is not harmful and in fact it is an advantage to have a certain bulk of this with each meal, as stated before in discussing nutrition, but the indigestible matter is pushed along the digestive canal and finally thrown out.

Then we have a real sewer system of pipes that start in the *kidneys*. See the drawing on Page 334 and note that the kidneys are in the abdomen, and next to the back. All the blood goes through the kidneys as often as once an hour. As it filters through very fine tubes the waste matter that was taken up by the blood as it circulated through the muscles, through the liver and through the nervous system is taken out by the kidneys. The sewage taken out by the kidneys we call *urine*. This urine is carried away from the kidneys by small tubes (ureters)—one from each kidney —to the bladder (the *urinary bladder*). From the bladder the urine is emptied every few hours.

Most of the waste matter that has to be thrown out of the body goes out in the three ways already mentioned. The solid waste (*feces*) is emptied from the *bowels*, the liquid waste (urine) from the bladder, and the gaseous waste (carbon dioxide) from the lungs. Besides these three kinds of waste leaving the body by the three exits named, there is a small amount of solid, liquid and gaseous waste leaving the surface of the skin.

The waste matter in the body is poisonous to the active cells of the body. If this poisonous waste is not promptly carried away from the body, cell work slows up and there may be a

serious disturbance of the normal orderly work of any of the organs. To keep in good health one should have regular emptying of the bowels at least once or twice every twenty-four hours. If anything interferes with getting the urine out of the body one would within a day or two be thrown into convulsions. If carbon dioxide is not thrown off, one would lose consciousness in a few minutes.

The throwing out of waste is thus a life and death concern. It is mostly under the control of the autonomic nervous system, and so can be regulated only indirectly by the reason and will.

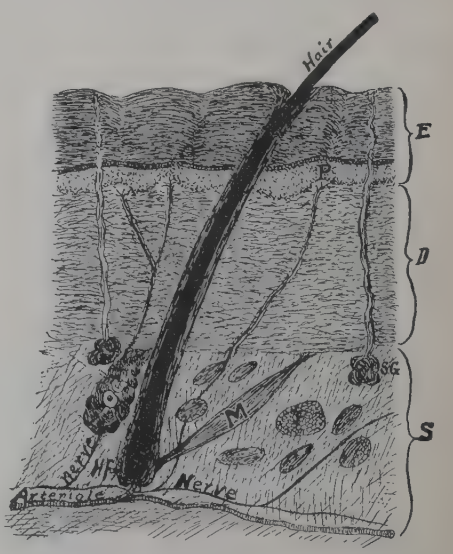
The most important rule of health that concerns excretion is: Drink plenty of pure water. How much is "plenty?" For a husky twelve-year-old scout six glasses a day would not be too much in the mild seasons (spring and fall) when there is little loss of water by perspiration. In summer eight or ten glasses would not be too much. Free use of pure water helps the body to rid itself of waste by three of the four exits: by bowels, kidneys and skin.

THE SKIN

WHEN we were describing the general plan of the body we called the skin an organ, because it performs a certain piece of work for the body. What is its work? Protection. In order to protect the body the skin is naturally outside, covering the vital tissues under it.

As told in the story of the cell, the skin as an organ is composed of three layers, each a tissue: the epidermis, the dermis or true skin and the subcutaneous tissue. There are also hairs and hair follicles, oil glands, sweat glands, nerve fibers and nerve endings. There are also arterioles and capillaries to bring food to the live, active cells of the middle or true skin, and there is a tiny muscle attached to each hair to straighten it up so it can "stand on end" when you get scared. The skin is a rather complex organ and it does various kinds of work. It makes oil to keep its texture soft and non-absorbent. It pours out perspiration from the sweat glands to protect you from heat (the evaporating perspiration cools you) and to help protect you from accumulating waste products.

Its hair muscles lift the hairs so that, standing on end, they make a thicker coat and protect from cold. Of course, this is very much more important for the horse or cow than for man. The rising hair gives the man only "gooseflesh," when he is chilly, as his thin crop of hair cannot really shield him from cold. But his hair rises, just the same—a heritage from the long ago.



THE SKIN AND THE HAIR

The skin is composed of three layers—an outer epidermis, or cuticle (E); a middle dermis (D); and an inner layer (S). Note also sweat glands (SG); papillae (P); hair folicles (HF), and oil glands (OG). Little muscles (M) lift the hair in fear, anger or cold.

If a scout drinks ten glasses of water in twenty-four hours in warm weather, it is probable that about half of the amount will leave the body by way of the skin (perspiration), perhaps two glasses by way of the kidneys (urine), two glasses by way of the lungs (vapor of breath) and the rest by way of the bowels (moistening the feces).

Suppose there have been several warm and rather dry days during which he drinks freely—perhaps ten glasses a day; then comes a cloudy, chilly, rainy day. What happens to the scout? His system is full of water. He is prepared for warm, dry weather but it is cool and wet. This is what happens. The skin will not carry off more than one or two glasses of the water as insensible perspiration and the lungs can throw off not more than one glass. The remainder will be thrown off by the kidneys. Thus the skin and kidneys help each other in their work.

The sense of touch

The skin is sensitive to touch (tactile sense), pressure, heat and cold. These sensations are general sensations as compared with the special senses. If you study the picture of the skin you will notice that the outer surface of the true skin (dermis) is not smooth, but is covered with little projections, (*papillae*). Each one of these papillae has a nerve ending in it and is thus sensitive to touch—it has the tactile sense. The whole surface of the skin has this sense though not equally acutely. For instance, hold two lead pencils side by side. Their points will be about three-eighths of an inch apart. Touch the double point of this combination to the tip of any one of your fingers or to your lips or tongue and you will instantly feel two points. Move the double point up along the inside of the finger up to the palm and across the palm to the wrist. At the wrist do you feel two points? No, you feel only one, though you see that two are touching. Now touch the double point to the back of the hand. It still feels like one point. Separate the two points and touch the double point to the back of the hand repeatedly as you separate the points, making them farther and farther apart until finally you can feel them as two points. How far apart are the points when the back of your hand can feel them as two? In this way you can test and find out where the touch sense is most acute and where least sensitive. It is important that the finger tips, lips and tongue tip are so sensitive in this touch sense. It does not matter that the touch sense is dull on your back or shoulders.

Take a lead pencil with a not too sharp point. Lay it where it will get cooled down to a little below room temperature. Touch the cool point to the back of your wrist. It may feel cool where you first touch it. Now move it along toward the tip of the middle finger. As the cool point moves over the skin, part of the time it feels cool and part of the time it does not.

If cold objects touch your skin, the nerves carry the message to the brain. The brain decides whether to do anything about it and what to do.

Similarly you can test with hot or rough or sharp objects. The skin's sensitiveness is a wonderful protection to the body.

Care of the skin—bathing and clothing

The skin, which is the protecting cover between you and the world, must be cared for and guarded. It must be washed and kept clean, partly for looks and partly for health. Exposed parts of the skin, hands, face, neck and the feet and legs of a barefoot boy should be washed every few hours. Because

oil and grease soil the skin, one needs to use soap to remove the dirt. Strong soap, used to "cut the grease" on the hands, may remove also the natural skin oil that keeps the skin soft. The parts so washed may become dry and rough and the skin may even get chapped, or broken. Use a mild soap, even on the hands, and especially on the face and neck. Rinse thoroughly with water until every bit of the soap is washed off. Dry the skin, not by rubbing vigorously, for that may roughen it, but by pressing the towel firmly against the hands or face until dry. Rub the hands together and rub the face and neck with the hands for a few minutes.

This rubbing of the dry, clean skin brings to the surface some of the natural oil and thus leaves the skin soft. With a little thoughtful care, one may keep his skin in the perfect condition that adds so much to his comfort and appearance.

Now for a shampoo

The hair and scalp must be kept clean. Mild soap should be used as a shampoo every two or three weeks. Rinse every bit of the soap out of the hair as the second stage of the shampoo. Dry the hair with a towel first, and then let sun and wind finish the task. Rub and massage the scalp vigorously a few minutes with the finger tips but do not scratch it with the finger nails. This brings out the natural hair oil from the little glands at the base of each hair. Brush vigorously to distribute the oil. Some one may smile and remark, "What beautiful hair you have, John!" You need not care. You know that you will have hair ten or twenty years after the neighbor who made the remark is as bald as a billiard ball.

If at any time your head (scalp) itches, do not scratch it. The itching is probably nature's way of letting you know that you need another shampoo. Wash it and the chances are twenty to one that the itching will stop. But do not wait for the itching to remind you of the need. Wash your hair regularly every two or three weeks. If your hair seems to be very oily naturally, it might be wise to take a shampoo every week.

Two kinds of baths

Take at least two baths a week, just for cleanliness, but besides these take a shower or a sponge bath or a dip in the lake or river or swimming pool every day during the warmer seasons, just for the toning up effect on the whole system.

The tonic bath should always be with cool or even with cold water and should be followed by a vigorous "rub down," so that when you are ready to dress your skin glows pink and you feel fit and fine.

The scout or the athlete usually "gets the habit" of the daily bath and rub down—a fine habit to follow through life for comfort, vigor and good health.

How clothing began and what it should do

When man began to move out of the warm countries where the race began, he found that for comfort he needed something to cover his natural coat. The mammals (horses, oxen, deer, elk, wolves, bears) that lived in cold countries grew long, thick hair for an overcoat. Man, killing an elk or a deer for meat, stripped off its warm coat and used it himself. Man's first clothing in cold countries was thus the hairy or furry skin of the animal he had killed in the chase. (See article on "Textiles" in next volume.)

But the women helped by spinning and weaving cloth from hair, wool, silk and cotton and soon people wore

clothing of many kinds, first for comfort and then for show as well. For show, one's clothing should be neat and clean; for comfort it should be well fitted and of a proper weight.

Courtesy American Leather Producers, Inc.

EARLY MAN MAKING A COAT

Man's first clothing in cold countries was the skin of an animal.

If it is uncomfortable to wear wool next to the skin, wear cotton, linen or silk. Be comfortable and neat.

THE SKIN AND THE SENSE OF TEMPERATURE

A thing may feel cool at one time and warm at another time, though the temperature is the same. As an experiment, place three dishes of water upon the table, one dish containing cold water, another with warm water, and the third with tepid (lukewarm) water. Hold the right hand in the cold water and the left hand in the warm water for one or two minutes. Then take the hands out and place them both in the tepid water. It will feel cold to the left hand and warm to the right hand.

The temperature sense warns the animal of the changes of temperature in the air or water, so that he may adapt himself to the change.

THE SENSE OF POSITION

If one were blindfolded and laid upon a table, he could easily tell if the table were lifted or tipped a little in one direction or another. He could easily tell the direction and he might even tell the amount, unless the movements were very, very slow. One can walk with the eyes shut or blindfolded; he can keep the erect position when riding a bicycle. Though we do all these things with the greatest ease, they really are difficult, if one stops to think about them. It takes a child nearly as long to learn them as to learn to read.

Sensations are carried to the brain from the various parts of the skin. If one is standing or walking, pressure on the soles of the feet will tell in which direction the body is swinging. On whatever part of the body one rests, the skin from that part sends messages to his brain, which enable him to tell the position of the body or changes in the position. The most important organ for sending messages to the brain regarding the position of the body is located within the internal ear. Through the aid of this organ, as we shall learn later in our story, the brain knows of all movements of the head as well as of all movements of the body through space.

THE NAILS—AN IMPORTANT APPENDAGE OF THE SKIN

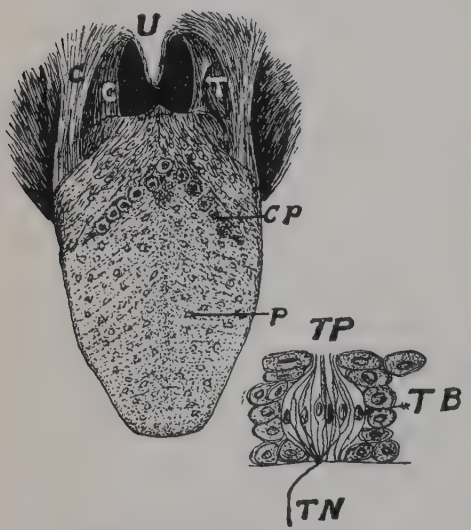
The skin has modified structures all over it, which are known collectively as the appendages of the skin. These are the nails, the hairs and their glands and the sweat glands. The cells of the skin become hardened and form the nails, which protect the fingers and toes. When we care for the nails they also add to the beauty of the hand. The substance of the nail is made up of clear compressed horny cells, each of which contains the remains of a nucleus.

THE SPECIAL SENSES

WE HAVE explored many parts of the human house and now we are to look at the activities that go on in the tower. Here are organs beautifully constructed and specialized to receive the special sensations. The *taste buds* attend to the receiving of taste sensations, the upper part of the *nose* receives odors, the *ear* receives sounds and the *eye* receives the multitudes of sight impressions. Well may these organs be called "the watchmen in the tower."

THE BUDS OF TASTE

The special organ of taste is the taste bud. There are hundreds and perhaps thousands of them, located on the surface of the tongue. Look at your tongue in the looking-glass. You will notice little red dots all over it. These dots are little fungus-like papillae or projections. If you can see the tongue very far back, you may see some larger papillae. All around the sides of the papillae there are little round bodies, composed of many spindle-shaped cells, between which lie the hair-like endings of the nerves of taste.



TONGUE AND TASTE BUD

Here we see the tongue extended showing the ordinary papillae (P), the circumvallate (meaning "surrounded by ridges") papillae (CP), the columns of the pharynx (C), the tonsils (one is shown at T) and the uvula (U).

The small drawing shows a taste bud. Hundreds of them surround the papillae. Each bud has a little pore (TP), an opening in which are the ends of the taste nerves (TN), whose branches lie between the spindle-shaped cells of the taste bud.

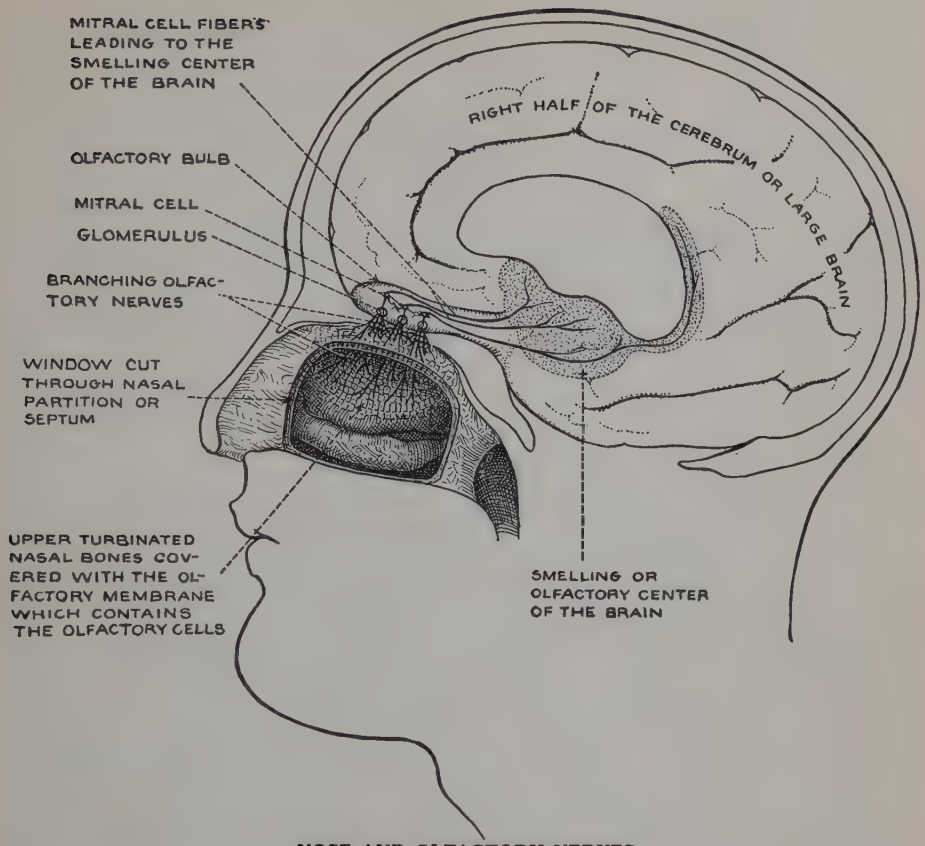
When a fluid or a solid dissolved in fluid, or one which may be dissolved by the saliva, is taken into the mouth, it comes into contact with these minute taste buds and stimulates the nerves of taste. These nerves send the message to the brain and one knows the taste of the substance.

There are only four different kinds of taste—salt, sour, bitter, sweet. Many of the sensations which we call taste are quite as much smell as taste. The flavor of cocoa or of roast meat is a sensation largely due to the sense of smell rather than to that of taste. Sensations which are combinations of taste and smell should be called flavors. When one has a cold in the head and both nostrils are completely stopped up so that he can breathe only through the mouth, the food tastes flat and flavorless. This is enough proof that the flavors depend upon a combined sensation of taste and smell.

A WATCHFUL GUARD IN THE TOWER—THE SENSE OF SMELL

The lower part of the nose, from the nostrils directly backward, is one of the air passages and part of the respiratory system, but the upper part of the nose, out of the direct line of breathing is devoted entirely to the sense of smell, and there are nerve cells in the nose in the mucous membrane among the cells which form the membrane.

Odorous substances in the form of gas or vapor may enter with the breathed-in air or may pass up from the pharynx with the breathed-out air,


MITRAL CELL FIBERS LEADING TO THE SMELLING CENTER OF THE BRAIN
OLFACTORY BULB
MITRAL CELL
GLOMERULUS
BRANCHING OLFACTORY NERVES
WINDOW CUT THROUGH NASAL PARTITION OR SEPTUM
UPPER TURBINATED NASAL BONES COVERED WITH THE OLFACTORY MEMBRANE WHICH CONTAINS THE OLFACTORY CELLS
RIGHT HALF OF THE CEREBRUM OR LARGE BRAIN
SMELLING OR OLFACTORY CENTER OF THE BRAIN

NOSE AND OLFACTORY NERVES

In this diagram we see that the olfactory bulb is really a part of the brain. From the lower surface of the bulb the olfactory nerves make a network which spreads over the olfactory membrane. This membrane carries the upper turbinated bones.

An odorous substance taken up by the olfactory membrane affects the olfactory cells and is carried by the glomeruli ("little balls") and affects the mitral cells, whose fibers carry the sensation to the smelling or olfactory center of the brain, where we experience the sense of smell.

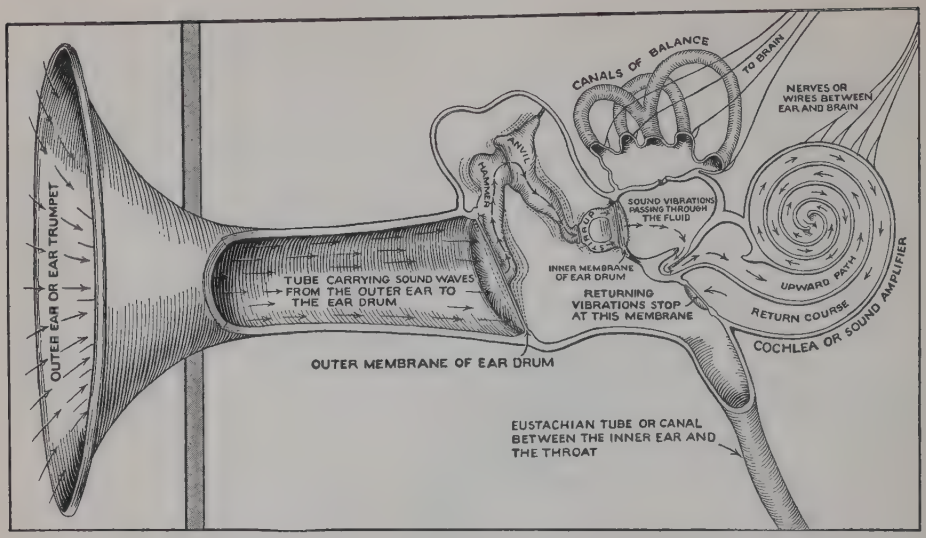
as is the case when one is chewing food. These odorous substances become dissolved or absorbed in the moisture which covers the membrane in the upper passages of the nose. They then come in contact with the nerve cells of smell in the membrane and these nerve cells send a message to the brain and one receives the sensation of the smell.

The different kinds of taste we found to be limited to four, but the different kinds of smell are countless.

Nature gives animals these senses seemingly for use in the choice of their foods. In the case of beasts of prey, the sense of smell may be used in tracking prey. Grass-eating animals may be guided by smell in the choice of food. A poisonous weed is rarely mistaken for a wholesome one.

Man can be guided by his sense of smell as to the wholesomeness of the air which he is breathing and his sense of taste and of smell will serve in part as a guide to the choice of food.

An odor is remembered longer than any other sensation. This sensation calls up more quickly and forcibly some past experience than does any other sense impression.


CANALS OF BALANCE
TO BRAIN
NERVES OR WIRES BETWEEN EAR AND BRAIN
ANVIL
HAMMER
SOUND VIBRATIONS PASSING THROUGH THE FLUID
OUTER EAR OR EAR TRUMPET
TUBE CARRYING SOUND WAVES FROM THE OUTER EAR TO THE EAR DRUM
INNER MEMBRANE OF EAR DRUM
RETURNING VIBRATIONS STOP AT THIS MEMBRANE
UPWARD PATH
RETURN COURSE
COCHLEA OR SOUND AMPLIFIER
OUTER MEMBRANE OF EAR DRUM
EUSTACHIAN TUBE OR CANAL BETWEEN THE INNER EAR AND THE THROAT

THE PATH OF THE SOUND WAVE TO THE BRAIN

This diagram shows the wonderful machinery of the human ear. The trumpet-shaped outer ear receives sounds from the outside world. The outer membrane of the ear drum vibrates and sets in motion the tiny hammer, anvil and stirrup bones. To the stirrup is attached the inner membrane of the ear drum, which vibrates. The waves pass through the fluid as shown and travel up to the nerves which act like telephone wires in sending the sensation of hearing to the exchange (brain).

The dotted lines show how the membranes and bones vibrate back and forth. Notice the tube that comes from the throat and fills the chamber of the inner ear with air, thus balancing the air pressure inside and outside the eardrum.

THE SOUND RECEIVERS IN THE TOWER—THE SENSE OF HEARING

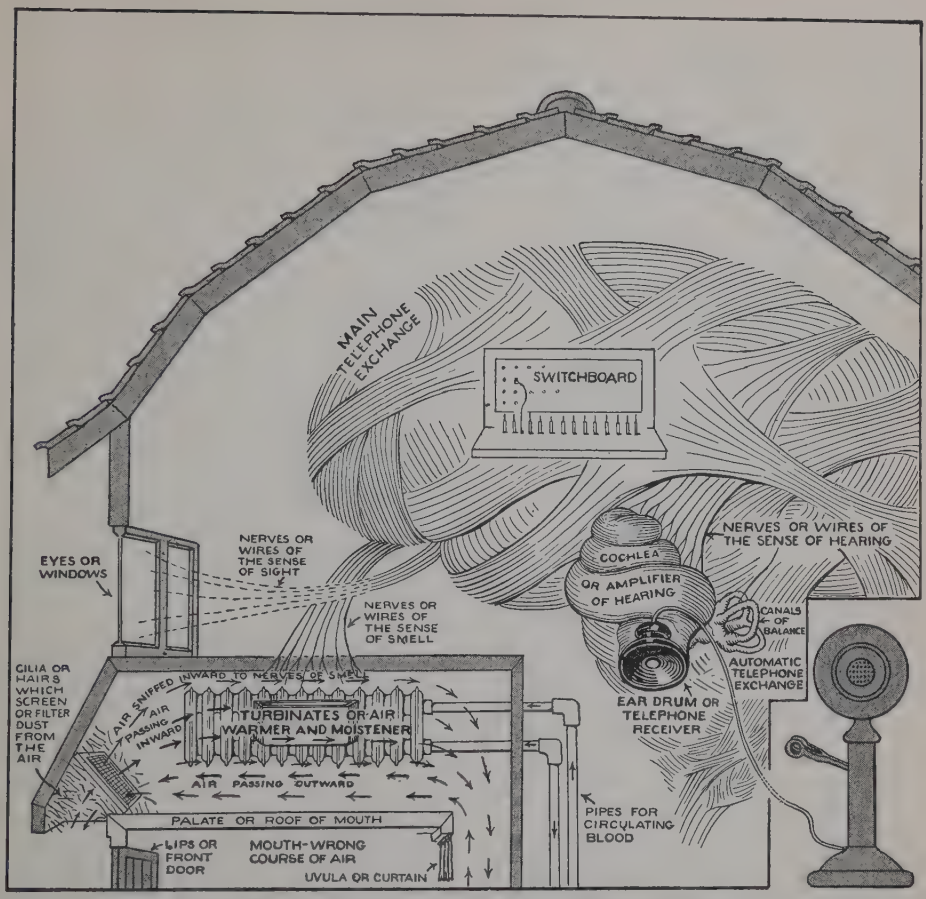
The ear is the special organ of the sense of hearing. All mammals and all birds have ears with which to hear and they all have voices. Rabbits, and some other animals, make sounds only on rare occasions.

That part of the ear which we can see on the outside of the head is only a sort of funnel for catching the sound and conducting it into the eardrum. Sound is not really heard till its effects reach the brain itself.

The outside ear, together with the passage to the eardrum is called the *outer ear*. The *middle ear* or eardrum is a little cavity in the solid bone of the side of the head. Still deeper in the bone is the *inner ear* where is located the real sound receiver.

The inner ear is made up of a *vestibule* from which open two chambers. One is coiled and looks like a snail shell. This is the *cochlea*, the real sound receiver. The other is a chamber that has three alleys or passage-ways that stand at right angles to each other. They are called *semi-circular canals*. These have nothing to do with hearing but they are wonderful organs that give us our sense of position and balance. They are indicated plainly in the diagram on this page.

The middle ear is called the *eardrum* or *tympanum*, a Latin word meaning drum, because it looks like a drum. As you know a drum has at least one head which is a vibrating membrane. The eardrum is more like a kettledrum because it has only one large, freely vibrating membrane. Opposite the main membrane is a small membrane, to which the foot of the stirrup bone is attached. Every drum must have a side opening or vent. If you stop up the vent of a drum the sound is muffled and dead because the membrane cannot vibrate freely. Try it on your drum.


MAIN TELEPHONE EXCHANGE
SWITCHBOARD
EYES OR WINDOWS
NERVES OR WIRES OF THE SENSE OF SIGHT
NERVES OR WIRES OF THE SENSE OF SMELL
NERVES OR WIRES OF THE SENSE OF HEARING
COCHLEA OR AMPLIFIER OF HEARING
CANALS OF BALANCE
AUTOMATIC TELEPHONE EXCHANGE
EAR DRUM OR TELEPHONE RECEIVER
CILIA OR HAIRS WHICH SCREEN OR FILTER DUST FROM THE AIR
AIR SNIFFED INWARD TO NERVES OF SMELL
AIR PASSING INWARD
TURBINATES OR AIR WARMER AND MOISTENER
AIR PASSING OUTWARD
PALATE OR ROOF OF MOUTH
LIPS OR FRONT DOOR
MOUTH-WRONG COURSE OF AIR
UVULA OR CURTAIN
PIPES FOR CIRCULATING BLOOD

BREATHING AND HEARING IN THE HUMAN HOUSE

Doubtless you have been told to breathe through your nose and not through your mouth, and this picture shows the reason why. The tiny hairs that line the entrance channel of the nose act as a screen to keep out dust and other harmful particles. The blood vessels and the turbinates are devices for warming and moistening the air. These safeguards do not work for us if we open the front door (lips) and, wrongly, breathe through the mouth.

In the sound amplifier (cochlea) incoming sounds are increased, just as they are in a radio loud speaker. The eardrum is like a telephone receiver receiving messages from the outside world.

The little canals of balance help you in every step you take, but the automatic telephone exchange which controls them relieves you from giving them the constant attention that they would otherwise demand.

This side opening into our eardrum is provided by our *eustachian tube*, which opens from the pharynx and passes up and back to the eardrum. Make a careful study of the drawing of the ear. Notice that the middle ear is separated from the canal of the outer ear by a membrane. This is the drum membrane referred to above. Sound waves beat upon the membrane and set it vibrating, just as the drumsticks in the hands of the drummer boy set his drumhead to vibrating.

The vibrations of the drum membrane are conducted across the drum by a curious set of tiny bone levers. There are three of these little bones called the hammer, anvil and stirrup because of their resemblance to these things. The stirrup has an oval foot that nearly fills a tiny oval opening or door in the wall of the vestibule.

The sound which beats upon the drum membrane makes it vibrate back and forth. That sets the three bones (hammer, anvil and stirrup) into vibra-

tion and thus the foot of the stirrup vibrates in the oval door of the vestibule and sets the fluid in the vestibule to vibrating. It vibrates in the same time or at the same rate as the vibrating drum membrane. These vibrations naturally throw the fluid in the snail shell, or cochlea, into vibration.

Stretched across the cochlea from its center to its circumference is a winding membrane about twelve times as wide at the upper end as at the lower. Along the edge stand living cells and between and around these cells there are the end fibers of the hearing or *auditory* nerve.

As the little membrane in the receiver of your telephone can receive for you not only every pitch but every quality of tone produced by a great orchestra, so this winding membrane of the cochlea vibrates in response to the sounds coming in through the outer and middle ear, giving the listener a perfect sense of pitch and quality of tones of all kinds.

The sense of hearing is one of the most useful guards in the tower. It warns of approaching danger while it is still at a distance. It enables one to hear at a great distance a call for help or a shout of warning. It enables people to exchange ideas. Through the ears we are made conscious of the joys and sorrows of our comrades. We hear their laughter as well as their sighs.

It is a part of nature's plan for the sense of hearing to be cultivated simply for pleasure. This may be observed even among the lower animals. The summer evening concerts of frogs, whippoorwills and nightingales and the morning concerts of robins, thrushes and other birds indicate that the voice and the hearing are to be cultivated together for entertainment. This is especially true for human beings. How much we would miss without the elevating and enriching influence of music!

The Care of the Ear

The most important thing to remember in the care of the ear is that no hard or irritating substance should be put into the canal of the ear because of the danger of injuring the delicate drum membrane. If wax collects in the ear canal it may be removed with the little finger covered with the handkerchief. If the wax hardens in the part of the ear next to the drum membrane it will cause discomfort and interfere with the hearing. Go to your doctor and he will soften it and remove it.

When one is swimming or diving he may get water in his ears. As a rule it will run out quickly when the head is held sidewise, so that the ear is down and the canal vertical, but sometimes a little mass of earwax near the drum membrane will catch the water like a valve, and, swelling up, will hold the water in the canal so that it does not flow out. Do not be disturbed. This experience may be uncomfortable, but it will not injure the ear. When you go to bed sleep with the watered ear down on the pillow. During the night the water will soften the wax and you will probably find the stain of the softened wax on the pillow in the morning. The water will have run out too.

Among a hundred young people, boy scouts, girl scouts or camp fire girls, in a summer camp, perhaps one of the camping party has had in the eardrum a serious inflammation that has left a little hole in the drum membrane. While this may not seriously interfere with the hearing it does make it dangerous to get the ear filled with water while swimming and diving and may start another inflammation in the eardrum which may even spread to nearby tissues.

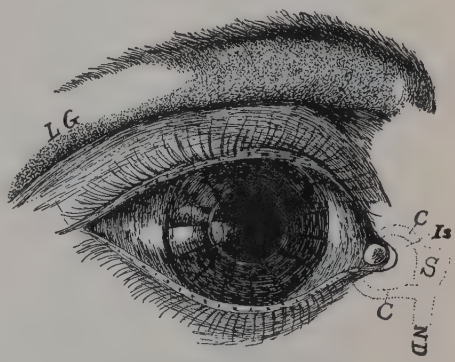
This does not mean that if you have a broken drum membrane you may not swim. Before you go into the water go to the camp health officer and he will fit a vaseline covered cotton plug tightly in the canal of the ear. This will keep the water out of the ear. Even with this protection do not try any diving.

THE CAMERAS OF THE OBSERVATION TOWER—THE SENSE OF SEEING

Seeing is one of the special senses and the eye is the special organ of this sense. The eye is one of the most complex organs of the body and the sense of sight is the most important of the special senses. The picture shows what you could see in a comrade's eye if you were to use a reading glass to magnify the parts somewhat. The eyeball is movable under the lids. It has a dense coat which shows in the corners of the eyes, but directly in front you see the black *pupil* of the eye, surrounded by the colored disk, brown in some eyes, gray or blue in others.

The eyeball is so delicate that it must be thoroughly protected from dust and all other injurious things. These protective parts, including the lashes, the brow and the tear apparatus, are called the appendages of the eye. The *eyelids* are the most important protectors of the eye, keeping its clear central portion moist and free from dust. On the edges of the lids, notice the little dots. These mark the opening of minute oil glands which oil the edges of the lids to keep the tears from overflowing.

Above the outer corner of the eye and under the brow is a gland about as large as the last joint on your little finger. This is the *tear gland*, and its secretion, mostly water, with a little salt and mucus in it, pours through the little ducts under the upper lid. When one winks the eye, the upper lid spreads the tears over the surface, washing off the dust and making the surface fresh and bright. The tears are constantly evaporating from the surface of the eyeball, but there are always some left over and these gradually collect down at the inner corner of the eye



THE EYE—A PICTURE

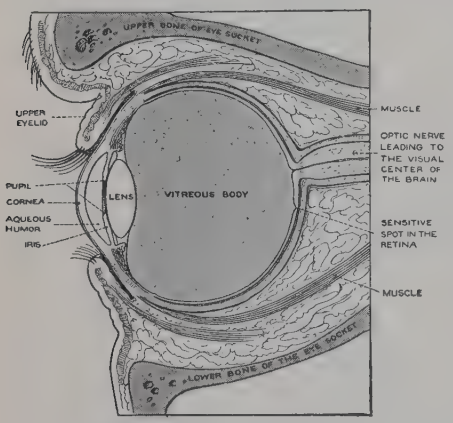
The tear glands (LG) wash the cornea when the eye winks. Any excess of tears will collect around the little island (Is) at the inner corner of the eye, and from here it will find its way to the canals (C) into the tear sac (S) and thence along the nasal duct (ND) into the nose where it helps keep the nasal membranes moist.

around a little island, which is marked "I" in the picture. On either side of this little island are two minute pores, leading into the tear canals. The two canals come together in what is called the tear-sac, from which a large tube, called the nasal duct, conducts the tears into the nasal passage. If the tears flow rapidly, they may come too fast to flow off through the little canals, and so may overflow upon the face. In that case they will also flow freely from the nose.

Among the appendages of the eye are the muscles which move the eye. There are six of these muscles. One turns the eye inward toward the nose, while the one opposite turns the eye outward. Then there are muscles which turn it upward or downward or in a slanting direction. Sometimes one or both of the muscles which turn the eye inward toward the nose are drawn too much. The person so

afflicted is said to be cross-eyed or to have a squint. A specialist is usually able, by a simple operation, to loosen the muscles enough to straighten the eye.

The eyeball is nearly round, and has a dense outer covering called the *sclerotic coat*. The front part of this coat is curved outward and is clear, reminding one of a watch crystal. This is called the *cornea*, and through this the rays of light pass into the eye. Just within the sclerotic coat is the *choroid*, which is a loose-meshed tissue, full of blood vessels and nerves. This



THE EYE—A DIAGRAM

Behind the clear cornea is the clear aqueous humor. In the center of the circular curtain, or iris, is the pupil. Back of the curtain is the crystalline lens. The vitreous body is a transparent space filler which would feel about like a gumdrop.

Muscles attached to the bony eye socket direct the movement of the eyes. The lens focuses a picture on the sensitive spot in the retina; the picture is photographed on the retina, and the impression is carried by the optic nerve to the brain, which really does the seeing.

coat contains an important muscular body called the *ciliary* muscle and it is this coat which makes the little colored curtain, the *iris*. The iris is like the diaphragm of a camera, and through it there is a circular opening called the pupil. The muscles which it contains may contract or expand the pupil according to the amount of light, or according to whether the object looked at is near or far away. They contract to see near objects and expand to see distant objects. The light which enters the eye through the cornea, passing through the pupil of the eye, must be focused upon the sensitive portion of the eye, the *retina*. The focusing is done by the *crystalline lens*. This lens is held in place by little bands, which pass out from the ciliary muscle. The contraction of this muscle will cause the lens to become more convex, or bulged out, thus focusing the light from near objects upon the retina.

The retina is composed of two coats. The outer coat consists of sepia-black coloring matter which absorbs the light while the inner coat consists of the nerve cells of sight. The eye nerve, or *optic* nerve, passes from the base of the brain direct to the ball of the eye and enters at the place shown in the drawing, the fibers spreading out to pass to the nerve cells of the retina. The most sensitive part of the retina is just at the outside of the optic nerve with which it is continuous. That part of the eyeball in front of the crystalline lens and back of the cornea is filled with a clear fluid called the *aqueous humor*. That part back of the crystalline lens and making up most of the ball is filled with a sticky liquid called the *vitreous humor*.

Wisdom in the Care of the Eyes

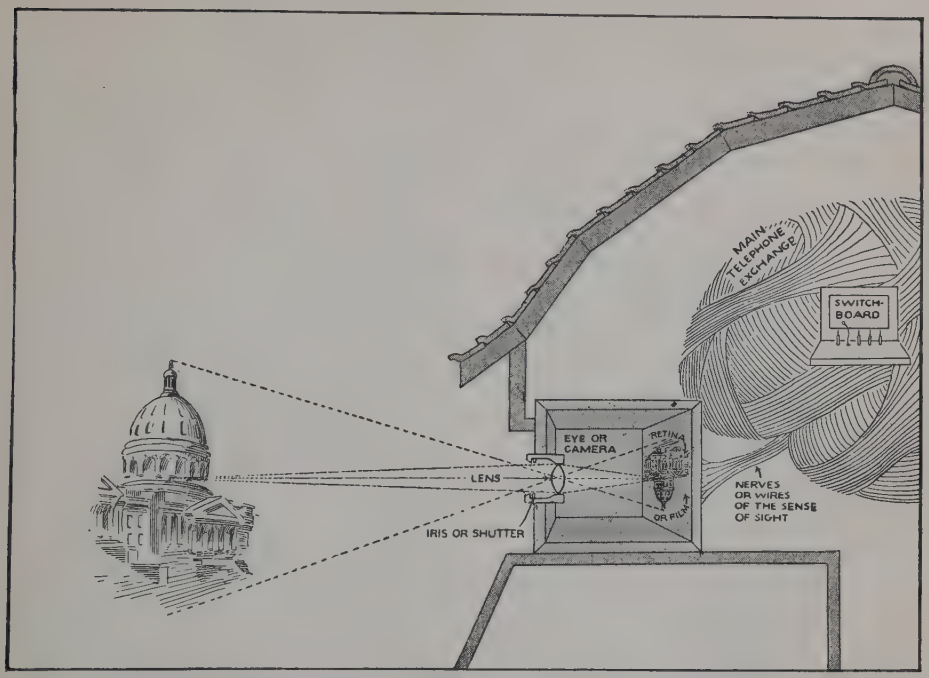
Never read by a dim light.

Never read by a flickering or rapidly changing light.

Never read in too bright a light. Do not read with the sun shining full upon the page.

Let the light shine upon the page and not upon the eyes. The light should fall upon the page from the side or from behind.

When the eye is at rest, distant objects are focused upon the retina. To see near objects it is necessary for the muscle which controls the lens to contract. To look constantly at near



THE EYE—THE CAMERA IN THE HUMAN HOUSE

The eyes, or windows of the human house, serve also as cameras. The building here shown gives off rays of light. The rays travel in straight lines in all directions. Some of them reach the lens and the picture is built up on the sensitive film (retina). The picture is actually upside down, but in some mysterious way that we do not understand the brain puts the view right side up. Thus we see the Capitol as it really is with the dome at the top and the steps at the bottom.

objects requires a constant contraction of this muscle. We know how hard it is to keep a muscle contracted for a long time and we can see that it would strain the eyes to look for a long time steadily at a close object. When reading a book or studying any close object, either close the eyes or look off at a distant object every few minutes to rest the eyes. If one has used the eyes too long and has tired them, bathing them in cold water is to be advised. If one cannot see clearly when looking at distant objects, or if one has headaches that can not be definitely traced to some other cause, he should consult a physician to see if the eyes need the assistance of glasses.

THE DIFFERENCE BETWEEN CONSCIOUS AND GENERAL SENSATIONS

You remember that in your scouting among live things on your hikes you found that all things that have life are sensitive and responsive to conditions about them. Among plants and the lowest animals there is no conscious sensation. Conscious sensation is found only in animals with brains.

The lowest kind of sensation is touch or feeling, which we have called general sensation because it is all over the body and there is no special organ. As a part or phase of feeling one is conscious of heat and cold, of pressure, tension and position of the body. All of these sensations are general sensations. They are conscious sensations among backboned animals, as dogs, birds, snakes, frogs, fishes; crusted animals, as insects and crabs and the higher mollusks, as the devil-fish. But the lower mollusks, as the clam or oyster, are not, we believe, conscious of any feeling. Yet if you touch a clam's gills between his

parted shell he quickly and firmly brings his shells together, shutting up "like a clam."

The special senses—smell, taste, hearing and seeing—cause conscious sensation. These special senses all have special organs. The specialized tissue in these organs is a modified, or changed, epidermis or modified nerve ending. Look at the taste bud—modified little nerve fibers lying between modified epidermal cells. Now look at the smelling organ, modified nerve cells lying between modified epidermal cells. If you could study the ear and the eye in their development and make-up as shown through a microscope you would find again epidermal parts and highly specialized nerve endings.

You now see that the special senses like the general senses depend upon skin and brain. One is conscious in his brain of conditions that the skin first senses or responds to.

THE SPECIAL SENSES AS WONDERFUL SERVANTS IN THE HOUSE

The special senses were given to animals for two great purposes. They afford protection against possible injury. From your observations on your hikes give examples of each sense in different animals, showing how the animal was protected by taste, smell, hearing or sight. These senses also reveal sources of supplies, as air, water, food. Can you give examples of this use of the senses?

In the highest animal, man, the special senses may give pleasure and gratification. In the enjoyment of the fragrance of flowers or the taste and flavor of delicious foods these two senses may gratify but they do not bring culture.

Hearing and seeing, the highest of all the senses, may be so cultivated as to lend much to culture and to the real and deeper pleasures and joys of life. Good music is enjoyed through the sense of hearing. Good pictures enter into our lives through the sense of sight.

We can understand clearly how the eye also may be the source of the highest pleasure and culture as one sees, studies and appreciates the beauties of nature in landscape, sea and sky. As one sees through telescope or microscope far-away things seem near or little things seem large, revealing beauty and wonders. The thought of the meaning of it all clears the understanding, broadens the mind and elevates the spirit.

Man has, through drawing, painting, architecture and various other arts that appeal to the eye, added much to the joy of living and to the elevation of thought above the plane of the common and the selfish.

MUSCLES AND BONES

WE COME to the last story of the departments of the house in which we live. We are now to learn about the framework of the building and how motion is produced through the motors, or muscles, and the levers, which are bones.

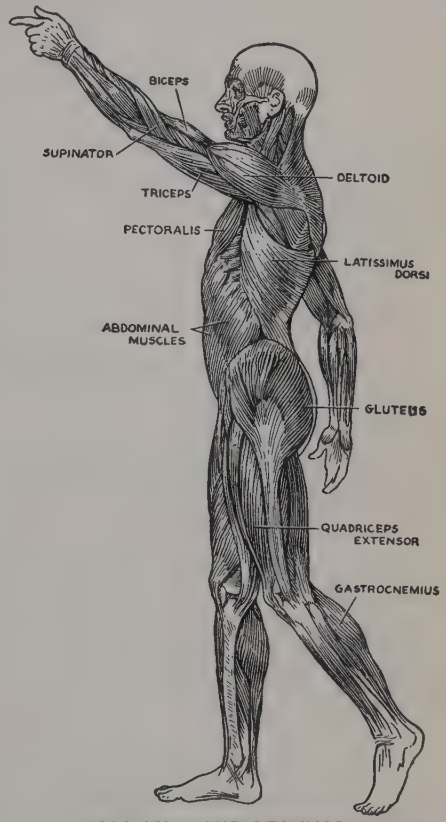
TWO KINDS OF MUSCLES AND GLISTENING WHITE CORDS

How would the body look if the skin and the layer of connective tissue and fat beneath the skin were all removed, leaving the muscles bare and open to view? Though many muscles are shown in the drawing, they are only a small part of all the muscles in the body. The picture shows only the outside muscles.

There are about five hundred *voluntary* muscles. The voluntary muscles are those that are under the control of the will. The muscles of the legs, arms, body, neck and face are all voluntary. Most of them are much larger than the *involuntary* muscles such as those in the walls of the stomach and intestines. They usually contract with a quicker and stronger action than do the involuntary muscles.

By studying the muscles of the arms and legs in the picture you will notice that the upper or middle parts are large and full and that from its largest part a muscle tapers down to a small white cord, or *tendon*, at the wrist or ankle. This cord is not made of muscular tissue but of very dense and inelastic connective tissue. If the full, round muscle extended down over the wrist and ankles it would make these as large as the forearm or calf and that would make the wrist and ankle very clumsy and awkward.

The glistening white cord spreads out into the shape of a fan at the end where the muscle fastens to it. The cord passes over the wrist or ankle, down to the hand or foot, where it is attached to the bone and through it the muscle can move the hands and feet with their fingers and toes.



HOW OUR MUSCLES WORK

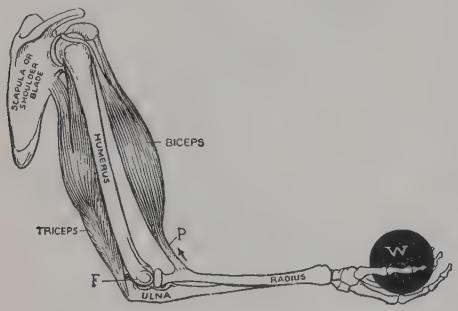
Here are some of our most important muscles. The deltoid ("shaped like a delta—△") lifts the arm; the biceps ("in two heads") bends the elbow; the triceps ("in three heads") straightens the arm; the supinator ("bend backward") turns the palm up; the pectoralis ("breast") draws the arm toward the chest; the latissimus dorsi ("broadest of the back") draws the arm down and back; the abdominal muscles draw the walls inward; the gluteus draws the thigh back; the quadriceps ("in four heads") extensor straightens the leg, and the gastrocnemius ("calf of the leg") lifts the heel. The gastrocnemius tendon unites with that of another muscle, the soleus, to form the tendon of Achilles.

Muscles are generally fastened to the bones at each end and use the bones as helpers. The bones serve as levers.

THREE KINDS OF LEVERS IN THE HUMAN HOUSE

The picture shows the bones of the arm and the two most important arm

muscles. In the position in which the arm is shown, the *biceps* muscle supports the weight which is resting in the hand. The bones of the forearm, that is, the *radius* and *ulna*, act as a lever. This lever is fastened at the elbow joint, that is, the elbow is the



A LEVER IN THE HUMAN HOUSE

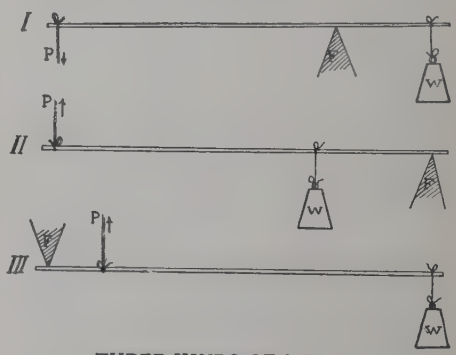
When the arm is in this position the biceps muscle represents the power (P) which pulls upon the lever (radius and ulna) between the fulcrum (F) and the weight (W) which rests in the hand. This is a lever of the third order.

fulcrum of the lever. The biceps muscle represents the power which pulls upon the lever between the fulcrum and the weight resting in the hand. When the fulcrum, the power and the weight are arranged in this way, the lever is said to be one of the third order. It is easy to see that a slight contraction, or shortening, of the biceps muscle will move the weight a greater distance than the actual shortening of the muscle. In all levers of the third order, the weight moves through a greater distance than the power, that is, there is a gain in the distance moved by the weight, but a loss in power.

The next picture shows the three orders of levers. In the lever of the first order, notice that the fulcrum is between the power and the weight. In the lever of the second order, the weight is between the fulcrum and the power, while in the third order, the power is between the fulcrum and the weight. In the lever of the first order, the power will move through a greater distance than the weight, as long as the fulcrum is nearer to the weight than to the power, but when the fulcrum gets nearer to the power than to the weight, the weight will move through a greater distance than the power. In a lever of the second order the weight is always nearer to the fulcrum than the power is, and will, therefore, always be greater than the power and will always move through a smaller distance than the power. In the third order the power is always nearer to the fulcrum than the weight is, and will, therefore, always be greater than the weight and move through a shorter distance than the weight.

Some Simple Experiments with Muscles

The leg of a chicken with the toes and some of the drumstick may be obtained from a butcher or from the



THREE KINDS OF LEVERS

Levers of the first, second and third orders are here numbered I, II and III. The weight to be lifted is W and represents the work to be done; the fulcrum is F and is the fixed point of the lever; the power is P and is the pull that accomplishes the work.

kitchen. Remove the skin and separate out the muscles and tendons. Notice the effect upon the movements of the toes when the different muscles or tendons are pulled.

Study the sketch of the different kinds of levers. What order of levers is the foot when you lift your weight upon the toes by a contraction of the

muscles on the back of the calf? What kind of lever does the foot make when, without putting the heel upon the floor, you lift a weight which rests upon your toes? What kind of a lever is the lower jaw during the process of chewing? What lever is the foot when you rest the weight of your body upon the heel? What order of levers do you make of your arm if you take a weight in the right hand and hold the right arm in such a way that the forearm will be horizontal and above your head, then, holding the upper arm still, straighten the arm, thus lifting the weight?

The hygiene of the muscles

You know that the work of the muscles consists in producing the motions of the body and in generating the heat which keeps the body warm. They produce these motions by shortening and thus pulling on their tendons and moving the bones. The stronger the muscles, the more work they are able to do, both in warming the body and in bodily movements.

The first thing required by the muscles is nourishing food and plenty of it. No part of the body is so sensitive to changes in the food as is the muscular system.

The value of exercise and rest

The muscles, like the brain and other organs, are developed by exercise. Nearly all young animals play. Play is nature's method of exercising and developing the muscles, brain and senses. Choose for exercise those movements which require quickness and accuracy, rather than those which require great strength. The best exercise is that obtained in games of skill and agility in which several persons are contesting. Engaged in a game, one loses all thoughts of himself and of the object of his exercise in his endeavors to win points in the game. Among the best games for the all-round development of the body are tennis, basket ball, hand ball, volley ball, baseball, cricket, football, lacrosse and golf.

Do not exercise severely within half an hour before a meal or within half an hour after a light meal or one hour after a heavy meal. Weariness is nature's notice to take a rest. When the brain and the muscles both call at the same time for more blood, the muscles will get it and the brain will not. For this reason, one should do his studying first and his playing or work afterward. If one goes out in the latter part of the day and takes vigorous muscular exercise or does his muscular work he will withdraw the extra blood from the brain, thus making it easier for the brain to rest at night in a dreamless, restful sleep.

The framework of the house—the bones

The earthworm has no framework. It cannot hold its body erect. All its movements must be slow and crawling. The butterfly has a framework. Parts of this framework support the delicate wings which are neatly united to the body. Through the aid of muscles which pass from the body to the framework of the wings, these may be moved, and the butterfly is enabled to fly out into the sunshine. The framework of an insect is on the outside of its body.

Man's body has a framework or bony skeleton, the parts of which lie deeply buried beneath the muscles. Without the framework man could not stand straight. The skeleton of man is very much like the skeleton of other backboned or *vertebrate* animals. All vertebrate animals possess a *vertebral column* or *body axis*.

When the dog is standing on all fours, his vertebral column is horizontal and his four legs pass downward to the ground as supports. The

four legs of the dog, together with the large flat bones which fasten them to the vertebral column, are called the appendages of the body axis. The *skull* is a part of the axis. The axis, or vertebral column, of the dog is extended backward beyond the body, the bones getting smaller and smaller to the tip of the tail.

In the case of man the axis, or vertebral column, does not extend beyond the body, but the last five bones are grown together into what appears, at first, to be one large, strong bone, called the *sacrum*. At the end of the sacrum there is the little *coccyx* of four button-like bones, usually grown together.

Some questions about bones

To what part of your body does the forepaw of a dog correspond?

Find upon a dog's body the part which corresponds to your elbow; to your knee; to your heel.

Find upon a horse's body the part which corresponds to your elbow.

What part of your body corresponds to the horse's knee; to the horse's hoof?

To what part of the horse's body does your heel correspond?

Study a dressed chicken and find upon the chicken the part which corresponds to your knee. Find the part which corresponds to your heel, to your elbow, to your wrist, to your fingers.

The hygiene of the bones

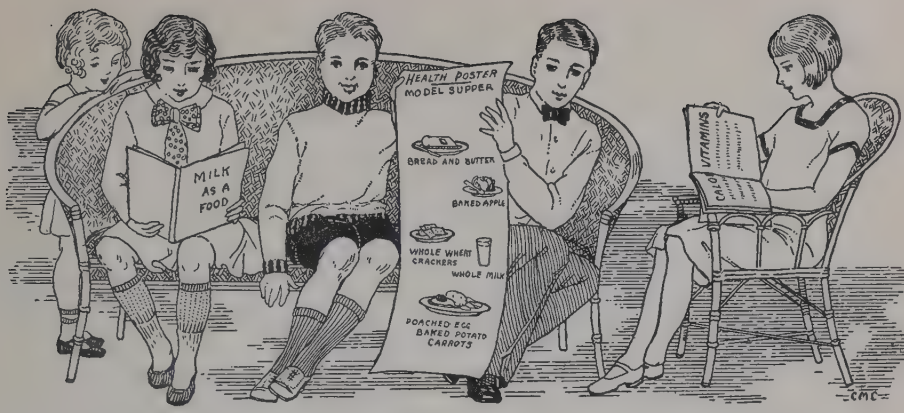
In infancy the bones are very limber and may be easily bent because they are composed mostly of *cartilage*, or gristle. As the child advances in age, the bones get stronger and stronger owing to deposits of lime within the bone tissue. If one takes a chicken bone and soaks it in vinegar or weak hydrochloric acid, he will find that the bone will gradually get softer and softer until it is limber enough to tie into a knot. This change in the bone is due to the mineral matter of the bone being dissolved out.

On the other hand, if one puts a bone into a fire and burns it until it is white, thus burning out all of the animal matter, he will find that it is brittle and can by crushed by the fingers. These two experiments teach us that a bone gets its stiffness and hardness from the mineral matter and its toughness and bending qualities from the animal matter which it contains.

It is easily seen that the bones of growing children need mineral matter and it is plain that this mineral matter must come through the food. Nature's infant food, milk, contains the proper amounts of mineral matter. For the infant up to six to eight months, milk is its only diet, and milk will continue for three or four years to be a large part of its diet. After the child is six or eight months old, other foods are added to the milk. These must be chosen with care in order to provide plenty of vitamins and bone-making material. The cereal foods, eggs, fruits and vegetables are best.

The bones of young people and children are very easily bent out of their proper shape because they have not yet become hard through the mineral matter. Little children in school or at home should not sit on high seats where the weight of the lower legs and feet hangs from the end of the thigh bone which rests upon the edge of the seat. Such treatment of this bone would bend it out of its natural shape.

Children should take great care to hold their bodies erect when sitting, standing, walking or riding. This requires some effort and attention at first, but if it is done faithfully not only is a good habit formed, but the bones and muscles later naturally take these positions.



FOOD VALUES

FOOD should do five things:

(1) Build up bone, muscle, gland and nerve tissue.

(2) Furnish fuel for life energy.

(3) Furnish the "life ferments" or vitamins.

(4) Furnish certain necessary minerals that are carried in fruit and vegetable acids.

(5) Furnish indigestible, but stimulating bulk of cellulose.

If a food has high fuel value, it is because it has abundant sugar, starch or fat and perhaps all of these. Cereals, dried fruits, legumes, nuts, cheese and fats all have high fuel value. In the cereals and legumes, the fuel value is due to the presence of starch; in dried fruits to sugar; in nuts, cheese and fats, to the oil. All of these foods are good fuels and some are also body builders.

If a food has a high building value, it is because it has much protein, as in milk, cereals, legumes, nuts, lean meats and eggs. All of these have high protein value and some of them have also high fuel value.

Foods with high bulk value (much cellulose) are helpful in stimulating normal action of the digestive canal. Cereals, vegetables and fruits are the sources of this bulk material. While the fresh fruits and vegetables have low fuel and building value they have high vitamin value and are thus a necessary part of the diet.

From the above facts it must be seen that for us human beings a mixed diet is absolutely necessary.

One must start life on a milk diet but early in infancy, at six to eight months, there should be added fruit juices, then thoroughly cooked cereals, cream and fruit pulp.

In early childhood the diet should be kept largely to milk, cereals, fruits, vegetables, eggs and nuts. In later childhood and youth, the scout age, one may use small portions of meat.

Most people have too large a fuel value in the diet, also too large a building value. Usually 2,500 to 3,000 calories per day is enough fuel. If this fuel value is taken from milk, eggs, cereals, vegetables and fruits there will be ample building material, bulk and vitamins.

The table on the following page will acquaint the reader with food values. Study the fuel, body building, cellulose, vitamin and other values and you will be better able to run the machinery in the wonderful human house.

TABLE OF FOOD VALUES

FOR THE MORE COMMON FOODS

No.	FOODS	Water	Nourishment	Waste	Fuel Value, Calories per Oz.	Body Building Value	Cellulose or Bulk Value	Fruit or Vegetable Acid Value	VITAMINS "A"	VITAMINS "B"	VITAMINS "C"	VITAMINS "D"	No.
	MILK AND MILK PRODUCTS:												
1	Whole milk, standard ½ pt.	87	13	0	20.4	***	0	0	***	**	*	**	1
2	Cream, standard ¼ glass	66	34	0	60.0	**	0	0	**	**	*	**	2
3	Butter, ordinary "pat"	6	92	2	227.0	0	0	0	***	0	0	**	3
4	Cheese, full cream 1 ½ cu. in.	37	63	0	122.0	**	0	0	**	0	0	0	4
	CEREALS:												
5	Wheat bread, whole wheat or Graham	10	86	4	104.0	***	***	0	*	**	0	0	5
6	Wheat bread, white, large slice	32	68	0	77.0	**	**	0	*	**	0	0	6
7	Oatmeal, dry in bulk	5	90	5	110.0	***	***	0	*	**	0	0	7
8	Oatmeal, porridge, large portion	85	14	1	18.0	***	***	0	*	**	0	0	8
9	Cornmeal, whole, unbolted	7	86	7	107.7	***	***	0	*	**	0	0	9
10	Hominy, cooked, large portion	80	19	1	24.0	***	***	0	*	**	0	0	10
11	Rice hulled, polished, dry	12	88	0	102.0	0	*	0	0	0	0	0	11
12	Rice boiled, large portion	72	28	0	32.0	0	*	0	0	0	0	0	12
13	Starch, cornstarch	2	98	0	114.0	0	0	0	0	0	0	0	13
14	Sugar, cane sugar	2	98	0	116.0	0	0	0	0	0	0	0	14
	LEGUMES:												
15	Beans or peas, dry	10	85	5	102.0	***	***	0	0	***	0	0	15
16	Peas, green, canned	85	14	1	15.8	***	***	0	**	**	*	0	16
17	Beans, green "string beans"	89	10	1	12.2	***	***	0	**	**	**	*	17
18	Peanuts, shelled and roasted	9	90	1	198.0	***	***	0	*	**	0	0	18
	NUTS:												
19	Pecans, shelled kernels	3	97	0	227.0	***	0	0	0	*	0	0	19
20	Almonds, shelled kernels	5	95	0	189.3	***	0	0	*	*	0	0	20
21	English walnuts	3	97	0	206.0	***	0	0	0	*	0	0	21
	VEGETABLES:												
22	Potatoes, white, not peeled	75	23	2	18.4	Trace	**	*	0	**	*	0	22
23	Potatoes, sweet, not peeled	69	27	4	27.5	Trace	**	*	**	*	0	0	23
24	Beets, boiled, peeled	87	10	3	10.0	0	***	*	0	*	0	0	24
25	Carrots, fresh, raw	83	10	7	10 0	0	***	**	**	**	**	0	25
26	Onions, fresh, raw	86	10	4	14.0	0	***	0	0	**	**	0	26
27	Turnips, fresh, white	93	5	2	7.5	0	***	0	0	**	0	0	27
28	Cabbage, fresh, raw	90	8	2	10.3	0	***	0	*	***	***	0	28
29	Spinach, fresh boiled	91	6	3	7.5	*	***	*	***	***	0	***	29
30	Tomatoes, fresh	92	6	2	6.5	0	**	***	**	***	***	0	30
31	Lettuce	94	6	0	6.5	Trace	***	*	**	**	***	**	31
	FRUITS:												
32	Apples, fresh	86	10	4	9.0	0	***	***	*	*	*	0	32
33	Strawberries, fresh	89	6	5	4.2	0	*	***	0	*	*	0	33
34	Orange pulp, seeded	89	6	5	4.2	0	*	***	*	**	**	0	34
35	Prunes, seeded	3	94	3	89.8	0	**	**	0	*	0	0	35
36	Figs, market condition	2	93	5	90.0	0	***	**	0	*	0	0	36
	MEAT, EGGS AND FATS:												
37	Porterhouse steak	52	37	11	58.7	***	0	0	0	0	0	0	37
38	Round steak or roast	61	32	7	55.6	***	0	0	0	0	0	0	38
39	Corned beef	49	38	13	77.8	**	0	0	0	0	0	0	39
40	Veal, leg of	68	28	4	43.4	**	0	0	0	0	0	0	40
41	Mutton, loin chops	42	42	16	88.4	**	0	0	0	0	0	0	41
42	Poultry, chicken	47	26	27	47.8	**	0	0	0	0	0	0	42
43	Fish, fresh	42	11	47	13.4	*	0	0	0	0	0	0	43
44	Fish, canned salmon	59	35	6	62.8	*	0	0	0	*	0	0	44
45	Oysters, fresh	88	10	2	14.7	*	0	0	0	0	0	0	45
46	Egg (one large egg, 4 oz.)	67	23	10	85.2	***	0	0	***	*	0	0	46
47	Fat, of beef, mutton, pork	6	90	4	200.0	0	0	0	*	0	0	**	47
48	Oils, vegetable oils	2	98	0	222.0	0	0	0	0	0	0	**	48
49	Oil, cod liver oil	2	98	0	222.0	0	0	0	0	0	0	***	49

EXPLANATION OF THE TABLE OF FOOD VALUES

Three stars (***) mean that the food so starred has the value indicated in a *high* degree. Two stars (**) mean *medium* value; one star (*) a *little* and (0) means *none*. These values are estimates only and cannot well be expressed in figures, but they are valuable and practical estimates, based upon long and careful study.

SAFETY PROBLEMS

WHEN you see a boy go by—for it usually is a boy—with a crutch, or with an arm in a splint, do you ever happen to think that nine times out of ten the accident has been the young person's fault? Pain and sorrow, lifelong disfigurement, and inability to take part in the work and pleasures of life follow carelessness—"taking a chance." This is an enormously important subject, although, perhaps, not a popular one; but, if you will bear with the writer for a half hour, you will acquire a knowledge of how accidents can be prevented.

In the World War, killed in action or died of wounds, we lost in round numbers about 54,000 soldiers, sailors and marines in a period of nineteen months. In 1935 about 100,000 persons were killed by accidents in twelve months. We put up memorials to the war dead and cherish the heroes and heroines in our hearts; but how about the slaughter that goes on every year? Taking the year 1934, where the figures are well checked up, 8,261 people died of burns; 23,828 from falls; 7,326 were drowned; only 1,610 were killed by machinery.

Now, everyone knows that machinery is dangerous, so how do you account for the small number of fatal accidents? The answer is that there are laws that require that workmen be protected from dangerous machinery. The insurance companies reduce the premiums on policies if machines are protected and if a few other safeguards not required by law are provided. Furthermore the larger industrial plants maintain hospitals where even minor injuries are treated immediately. Similar slight injuries are often neglected when they occur in the home. From this discussion you will see that the workman is really safer in his factory than he is at home or journeying to and from his daily tasks.

This brings up the question of accidents on the streets and in public conveyances. The automobile tops the list. In 1935, there were 37,000 dead and 1,300,000 injured in the trail of automobiles as they sped over the streets and roads. As the sun went down each day the toll was 101 dead, over 3,500 injured. It makes an ordinary war, like the one with Spain, look like a game. In 1934, electric railways killed 884. The accidents to railroad passengers were only 39.

A DANGEROUS PRACTICE

Stealing rides on trolley cars is dangerous and leads to the fatal freight train.

In 1934 there were 15,306 children under fifteen years of age killed by accidents. Parents will guard their children against diseases, yet will allow them to "hitch" on an ice wagon with all its dangers. Among children from one to fourteen years old accidents result in more deaths than pneumonia, and more than twice as many as any other children's disease. The responsibility is very much divided. Children need better instruction.

The dangers of fire

Let us begin with the home. The worst danger is that of fire. If you live in an apartment in the city, see that the fire escapes are not blocked up. Do not leave matches around where young children may play with them. Use safety matches exclusively. If you burn gas have wire or other protectors which will keep curtains away from the flame. Try being your own fire marshal. Inspect the house; clean up rubbish; look out for oily rags, kerosene and gasoline cans and keep them in airtight cans. A fire extinguisher is an excellent thing to have in the house. The advice for a house is about the same, except to look out for the cellar, which is apt to become a catch-all for rubbish. Look out for Christmas trees when lighted. If possible, use the little electric bulbs rather than candles. If you burn gas see that the flame is away from the woodwork. Flues should be kept clean. Electric appliances should be kept in order. If you want to get valuable information on the use of gas and electricity and concerning fire hazards, send to the Superintendent of Public Documents, Washington, D. C., for Circular No. 75, Bureau of Standards, "Safety in the Household." It costs only fifteen cents, but do not send stamps, for Uncle Sam has no use for them in this connection and wants a money order or real money.

How to avoid accidents by fire

Fill kerosene lamps in the daytime. Never use kerosene to light fires. In using gasoline or naphtha for cleaning keep away from fires; have the windows open, or stay outdoors. Do not try to locate a gas leak with a lighted lamp, candle, or match. Use a flashlight or cover the pipe with soapy water and watch for bubbles to form. Remember that celluloid is very inflammable. Be sure to turn off the current when you have finished using an electric iron or any electric utensil. If there is any trouble with your electric wiring send for an electrician. See that the aerial for your radio is not near an electric supply line. Protect all curtains from gas jets. The draft from nearby windows may cause fires which are quick to spread but very difficult to extinguish. Never allow cigarettes or matches to be thrown into waste paper baskets, or other places containing inflammable material.

What to do in case of fire

Keep your mind on what you are doing. Act quickly. Summon help if anyone is within calling distance. If the blaze is small and you think you can put it out by devices which are handy either

1. Use a fire extinguisher or siphon of mineral water, or
2. Use a woolen blanket or rug to smother the fire. Keep the air from the fire, or
3. Throw water on the fire from a pail, using a broom if it be conveniently at hand. If not, splash the water with the hands. Do not use water on an oil or grease fire; use sand or earth from flowerpots, or
4. Beat down any draperies, curtains or light materials causing the blaze, using a broom or long pole. (Using bare hands may cause serious burns. A wet broom is much more effective.)

It is very dangerous for women to stamp out fire, on account of the nature of their clothing.

Unless you are very sure that you can handle the fire without help, notify the Fire Department, or have some one else do this. In many cities it is necessary only to call the Fire Department on the telephone. In others it is necessary to send an alarm at a corner fire box. The methods used for turning in

alarms are often not understood, and as seconds count it is important that they should be studied before fires occur. The telephone number of the Fire Department should have a place at each telephone. In giving information about a fire over the telephone, one should carefully consider what he is doing. The few seconds lost in doing this are positively not wasted. What a Fire Department wants to know is (1) the number of the house, (2) the name of the street or road, and (3) the nearest street corner.

Cut off all draft, closing doors, windows, and closets in the room, and use handy methods of fire extinguishing as mentioned above. Tie a wet towel or any other material (preferably of wool) over the mouth and nose if you are fighting the fire and are exposed to smoke or flames. It is said that more people lose their lives by suffocation than through burning. Place yourself so that you can retreat in the direction of a safe exit without passing through the burning area. Unless you can do something worth while, get out of the building. Investigate afterwards. If it is necessary to go through a room full of smoke keep close to the floor. It is usually better to crawl on the hands and knees, keeping the mouth close to the floor. The drafts and air currents cause the smoke to rise and the air nearest the floor is usually the purest.

Do not jump from a high window. Use a rope or life line. To slide down a rope, twist the rope around one leg and, holding the feet together, regulate the speed of descent. Otherwise the hands may be painfully injured, especially if the height is great. Sheets and other articles of bedding will often provide a life line if knots are carefully made so that they will not slip. An extra loop in the knot may avoid this danger. Tie the rope or life line to a bed or other article of furniture which will not pull through the window. The line should not be thrown out of the window until the instant it is needed.

A person with clothes afire will only make conditions worse by running. Particularly avoid running out of the house. Running fans the fire. If your clothing is on fire, quickly wrap yourself in some heavy material and roll on the floor. A rug, shawl, bed cover, portieres or a coat will serve the purpose well. It is better to put out the fire in this manner than by the use of water, unless a considerable body of water is near.

If you see a person with clothing afire, wrap him up and roll him over. It will often be necessary to throw him down on the floor by force, due to the fear which the blazing clothing causes.

THE FENCE CLIMBER
Many a boy gets hurt climbing picket fences.

LOOK OUT FOR FALLS

Falls are the commonest form of accident, and attack everyone alike where there is carelessness or improper conditions. Edward Whymper, the famous mountaineer, was the first man to ascend the Matterhorn, a very high and steep peak in Switzerland. Later, Whymper fell downstairs in his house in London and broke his collar bone. Where there are young children there

CHILDREN SHOULD AVOID THESE DANGEROUS PRACTICES

Children should keep away from medicine cabinets.

Many a broken leg has come from porch climbing.

A dangerous practice; suppose the ice should slip.

Never climb an electric light pole; you may touch a live wire.

should always be a gate at the head of the stairs and windows should have some form of protection, for many small children have lost their lives by falling from windows. Children should avoid scampering on stairs and should never slide down the balustrade. Stairs should be lighted at all times in order to avoid accidents. When stairs are being cleaned look out for cakes of soap, pails of water and slippery wood. Small rugs at the top of stairs have caused many falls.

Loose rugs on polished floors are another fertile source of trouble. One of the greatest dangers is in rushing through imperfectly lighted rooms to answer a telephone or open a door. Falls in bathtubs are frequent. Standing on a chair is a common way of getting hurt. If the chair be a rocking chair, so much the worse. If you must do any climbing, use a stepladder and see that it is firmly braced before trying to go up. Never put tools on top of a ladder; you may move the ladder suddenly and the tools will come down on your head. Boxes, crates and barrels are poor substitutes for a ladder. Projecting nails may aggravate the danger. Remember that you do not have to fall off a roof to be injured. A fall of two or three feet is often fatal. If you use an ordinary ladder have someone hold it while you are on it. If you are going up very far and have articles to take with you, such as a pail of paint, draw it up afterwards by a rope. Never allow children to climb a porch or a telegraph or electric light pole. They *will* climb trees, but keep an eye on this activity.

Injuries from nails

In New York State alone there are thousands injured each year by nails. Remember that there is no part of the body which cannot be injured by nails. A sharp nail may penetrate your foot and give you trouble. Whenever you see a loose board with nails sticking out, get a hammer and bend them down, or take them out entirely. Tell all your friends about the nail danger, and ask them to pass on the warning. Boards with nails removed can be packed up tidily and a supply of lumber is a big asset to the boy mechanic.

THE DEFECTIVE LADDER

Many a bad fall is due to the use of a poorly constructed or defective ladder. (Photograph from Safety Bureau, Buffalo Chamber of Commerce.)

Cuts and bruises

Never use a tool with which you are not acquainted. Sometimes tools injure by being too sharp; sometimes by being too dull. Have all tools examined by an older person and get advice as to their use. Beware of hammer heads and axe and hatchet heads that

VISUALIZING SAFETY FOR MOTORISTS AND WALKERS

The Safety Council of Providence, R. I., built this model to teach safety. See what each figure points out.

1—To help tracks' muddiness should travel in more than one lane of traffic. 2—Walkers should go with traffic, not across it. 3—Don't be a jaywalker. 4—Don't park too close to corner. 5—Driver cut in too quickly. 6—Too great speed causes most accidents. 7—Walker at fault in coming quickly from between parked machines. 8—Driver should signal when coming out of a parking space. 9—Don't cross at middle of block. 10—Don't step off here, it is dangerous. 11—Driving with poor brakes and following tracks too closely. 12—Most collisions occur at intersections. 13—Improper parking. 14—Walker at fault. 15—Driver at fault in passing a stopping trolley. 16—Driver at fault for cutting corner. 17—Driver did not give right of way. 18—Driver should give consideration to walkers on crosswalks.

might come off. Old tins and pieces of glass and crockery make nasty cuts which should be attended to at once. Wash with hot or cold water, paint or rub with iodine and wind with a clean strip of bandage which should always be kept in roll form in the medicine closet. Twenty yards of two-inch bandage should always be on hand. A clean, old linen handkerchief is a good substitute for a bandage. Tie well but not too tightly, or fasten with small safety pins. Inattention to proper precautions may result in a serious case of blood poisoning. When we see the care given to cuts in a factory and see how more serious injuries are neglected in the home, we feel that advice like this should be heeded.

Bruised fingers are most painful. Try putting the fingers into hot water, and, if seriously bruised, paint with iodine. Arnica is also good to put on bruises. If the bruise is at all serious consult a physician.

Swallowing articles

If a child, usually an infant, has swallowed anything, it is generally a case for the doctor, who has instruments with which to remove any article; but if the child can be "upended" and the coin or safety pin shaken out, so much the better. Quick action is absolutely necessary.

The toll of fireworks

Every year thousands of persons are injured in Fourth of July celebrations. In 1935 at least 7,738 met with accidents and at least 30 were killed, handling fireworks and matches and making bonfires. The WPA made a study of these 1935 casualties and among their findings discovered: 817 children between the ages of one and ten were injured and 13 of this age group were killed; 6 children between the ages of 10 and 15 gave up their lives; more than 2,800 of the injured required medical care and over 2,500 were taken to hospitals. The common firecracker caused the most accidents; followed by cherry bombs, torpedoes, cannon crackers and sparklers. Think this over when the Fourth of July comes around, and talk it over in the family.

The danger from poisons

Medicines and drugs should be kept in one place. Poisons should be carefully labeled and the family should be told not to touch such bottles. Never take medicine out of a medicine closet in the dark. Insect killers and garden sprays are often poisonous, and should be kept where young people cannot get at them. Cans of lye are a very common source of injury to young children.

Safety on the street

The problem of street safety is the most serious danger we have. It affects everyone. The best engineers in the country, from Herbert Hoover down, have given it their serious attention with not a great deal of success. We can give only a few general hints.

The first and greatest rule is never cross the street except at the crossings. If traffic is regulated by an officer or by lights wait for the signal and then make the crossing—in safety. Don't "jay walk." The crossing of streets in the middle of the block has filled our hospitals with victims and our homes with grief. Wait five minutes if necessary, to make a safe crossing. Roller skating is often a real peril, especially when going down a hill. We have often seen children coasting down hill with a pointed stick in the hand—a double danger. Never "hitch" on wagons when on roller skates or on a bicycle or on foot. Do not try to get stolen rides on street cars. Many a poor little chap is minus an arm or a

leg for such rides. Never play in a crowded street where there is automobile traffic. Boy Scouts get lots of fun without danger. They are forewarned. Never touch a fallen wire on the street. It may bring you sudden death.

A very good method is to study and observe the ten safety commandments of the New York Police Department, which are as follows:

(For Pedestrians)

1. Cross streets only at regular crossings.
2. Don't cross streets directly behind a street car.
3. Wait till traffic stops before crossing streets.
4. Don't cross streets diagonally—go straight across.
5. Look both ways as you cross the street.

(For Motorists)

6. Look out for children.
7. Give the pedestrian a chance.
8. Drive carefully at all times.
9. Keep your brakes in good order.
10. Study traffic regulations; obey them; they are laws.

Safety in public places

Special attention has been given to safeguarding people in places of public amusement. Theaters have carefully designed exits, fireproof curtains and a fireman is usually in attendance. It is not so much the fire that must be guarded against as the "panic hazard." Try to exercise self-control in all emergencies. Remember what Admiral Farragut said: "The coolest officers are the best." Emergencies will sometimes come into your life. Be prepared, be brave, be cool, be efficient. When you are at a hotel always find the nearest red light which shows a fire escape. Loss of life by fire in hotels is very great; with proper precautions it is largely preventable.

Umbrellas, though useful articles, should be carried so as not to cause others to fall, especially in street cars. In a crowded elevator try to give the operator plenty of room to run the car. Do not shove or push when in a crowd, and never say anything which would alarm your neighbor and produce a panic. Look out for glass doors and push them gently, for, if the glass breaks, you may be seriously injured. Do not run up and down stairs. Always keep to the right, no matter where you are.

Safety on the railroad

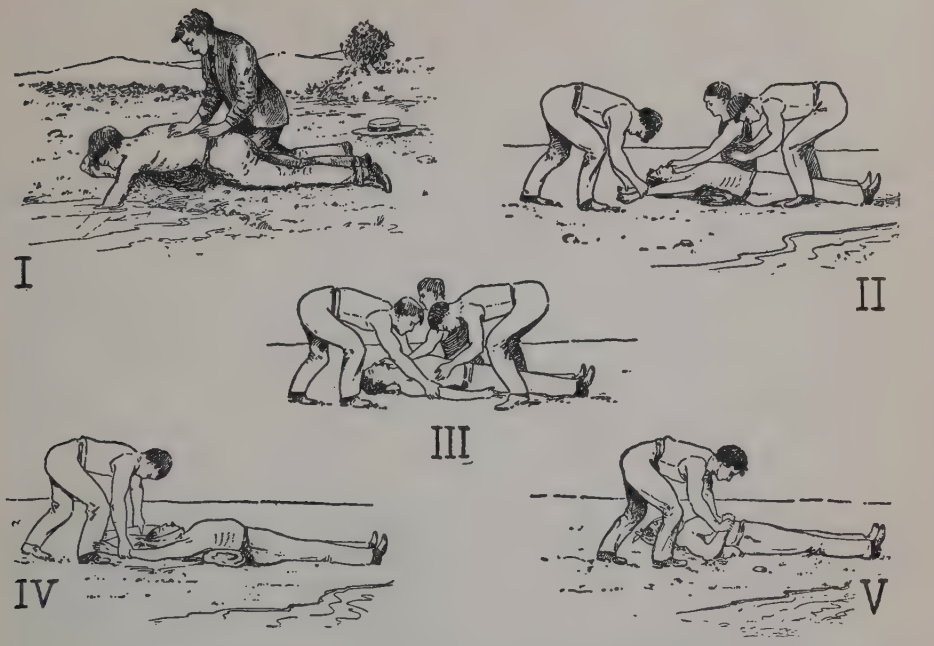
Always allow plenty of time to catch a train. When your train is called go to your car, take your seat and arrange your hand baggage. Do not leave your baggage in the aisle where somebody may stumble over it. Remember that overhead baggage racks are not intended for heavy suitcases or large parcels. Many accidents have been caused by improperly placed articles tumbling out when rounding curves. Do not attempt to ride on the steps or platform when the train begins to move. Under no circumstances try to get on and off cars that are moving. Always ask the trainman or conductor if you have the right train before you get aboard. When opening a window see that it is properly secured so that it will not come down on your hand. Never put your head or arms out of a window. Do not throw anything out of the window for you may hit somebody.

In most states the common drinking cup is forbidden. Buy a paper cup. It is a cent well spent.

There are other dangers to those who are not passengers, but trespassers. Always remember that

"It is never right to play
On the railroad right of way."

The number of trespassers killed on



Courtesy Scientific American Cyclopedia of Formulas

ARTIFICIAL BREATHING IN TREATMENT OF THE DROWNING

I—Expelling water from the body. II—Movements to produce inspiration. III—Movements to produce expiration. IV—Movements by one person to produce inspiration. V—Movements by one person to produce expiration.

the railroads of the United States in 1933 was 2,826. Do not play about freight cars. Keep away from railroad yards and grade crossings. They are unsafe play places for children. The slaughter of automobile passengers at grade crossings is enormous.

Safety on the Steamboat

Always allow plenty of time to get to the dock. It is dangerous for children to play on the dock. When the boat arrives do not try to be the first one on board. Many accidents are caused by rushing upon the gangplank. Move steadily with the crowd and seek the middle of the plank so that you will not be forced off the sides into the water. Select your deck and your seat where you will be comfortable. Look around you and note where life preservers are kept. Only one in each 3,456,372 passengers is lost, so the steamboat is as safe as the steam railway; but it is well to be careful. Do not run up and down the stairs or companionways. A sudden change in course may cause a fall. Do not throw fruit skins on the decks. Somebody might slip on them and fall. When landing do not try to be the first off the boat, particularly at night.

Apparent Drowning, Gas Asphyxiation and Electric Shock

If a doctor or a pulmotor is not to be had whenever a person is apparently drowned, shocked by electricity or asphyxiated by gas of any kind, the Prone Pressure Method may be used with great chance of success if you set to work at once.

Lay the patient on his stomach with arms extended ahead to expand the chest, and with his face to one side to permit free breathing. Clear the mouth of mucus, tobacco and false teeth. Loosen clothing at throat. In

case of drowning, first clasp your hands under the patient's stomach, lift him several times, letting the head hang down to drain out the water and have the patient's head lower than his body before starting artificial respiration. Place a stick of wood, a coat rolled up, or both, under the pit of the stomach. Don't wait for anything, but start at once.

Kneel, straddling the patient's thighs, with palms of your hands on his loins; your thumbs nearly touching and your fingers spread over his lowest, or floating ribs.

First motion: Slowly swing your body forward until your weight is on your hands. This presses the air out of the lungs.

Second motion: Swing back onto your knees to relieve the pressure. This allows the chest to expand and draws air into the lungs.

Keep up these motions deliberately at the rate of from sixteen to twenty a minute, about as fast as you breathe. Don't give up too soon, and don't give anything by mouth until patient is fully conscious.

Practice this once or twice and you are then ready to save a life.

A FEW OF THE THOUSAND AND ONE WAYS OF NOT GETTING HURT

We cannot give them all, but these are important ones.

Do not play around piles of lumber or unfinished buildings.

Do not play with electric cable reels. They have a fashion of turning over and crushing bones.

Never climb ladders or walk on scaffolds.

Do not run on the street for a ball unless you are sure that there is no vehicle approaching.

Never play with a parked automobile. You may start it.

Be careful about swimming. Do not swim in lonely places where you cannot get help.

If you are subject to cramps, do not leave shallow water.

Avoid drinking very cold water after bathing.

Do not skate on ponds, canals or rivers where the ice is thin. Always skate in parties, but do not stand on the ice in a crowd.

Keep away from poison ivy. For treatment of ivy poisoning refer to Page 148.

Do not eat highly colored berries you find along the wayside.

DO NOT STEAL A HITCH

This is a dangerous practice and a fertile source of accidents.

Never eat food from a can which "buckles," or is bulged at the ends, for fermentation has probably set in and the food is poisonous.

Never throw anything out of a window.

Do not stand under a tree during a thunderstorm.

Never touch a bottle supposed to contain whiskey or gin. It may be made from wood alcohol, and may produce blindness, even death.

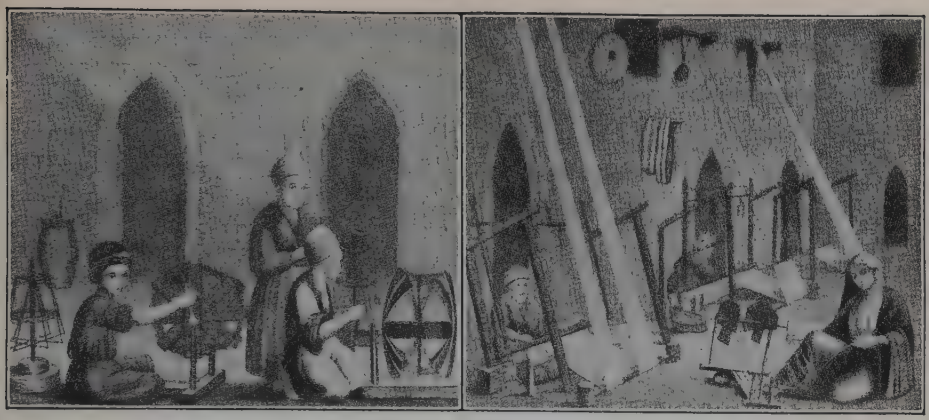
Be careful around bonfires. This is a dangerous sport at best.

Book *of* Invention and Engineering

The Industrial Revolution
Telegraph, Telephone and Cable
Radiotelegraphy
Radiotelephony
Pictures by Wire or Wireless
X-Rays
Radium
Bridges
Lighthouses
Power at Niagara Falls
Water Navigation
Railroads
Underground Engineering
Navigation of the Air
A Table of Great Inventions

THE LABORATORY

Modern invention and engineering are largely dependent on the well-equipped experimental and testing laboratory.



ANCIENT EGYPTIANS SPINNING AND WEAVING
These pictures (after an old print) depict spinning and weaving as carried on in the days of the Pharaohs.

THE INDUSTRIAL REVOLUTION

AS recently as 1765, men were spinning and weaving very much as they did in the days of the Pharaohs. There were no factories, no machines, no industrial cities. Forty years later a tremendous change had been brought about. The north central portion of England had become one humming hive of industry. Great factories throbbed with life and power. The modern system had begun. There have been fewer industrial changes in the last one hundred twenty years than in the forty which came just before this time.

This period in the world's history is known as the Industrial Revolution. The thoughts of the human race seem to run in certain channels at certain times. There never was a time when pure reasoning was as clear as in the hundred years when Plato learned from Socrates, and in turn taught Aristotle. Certain poetic powers seemed to reach their height in the age of Dante, 500 years ago. There never has been a time when architects and artists produced such wonderful works as did the men of the late Middle Ages. The period from 1750 to 1790 produced a great wave of mechanical inventions. The names which we associate with it are Kay, Hargreaves, Watt, Arkwright, Cartwright, Crompton.

The story of progress is interesting when one sees how progress moves on resistlessly, in spite of the attempts of foolish and short-sighted people to hold it back. Nearly every one of the great inventions which have lightened human labor and have cheapened the cost of living had to fight its way against the most determined opposition. Ignorant mobs broke the new machinery and burned the new factories, and still more ignorant public opinion stood by and watched this vandalism with approval. However, these outbreaks were like the attempts of the old woman with her broom, trying to beat back the rising tide. The march of progress, hampered, retarded slightly at intervals, has continued steadily.

The Industrial Revolution had to do chiefly with the making of cloth, and the loom was the subject of practically all of the great changes that were effected. Spinning and weaving had been a tedious process. The spinning

wheel, invented during the time of Queen Elizabeth, had been the one forward step taken since the days of the early Egyptians. In order to make clear to our younger readers just what we are talking about, one must bear in mind that cloth is made from threads. These threads are made by twisting or spinning the pieces of wool or of cotton fiber or of flax, until they become long, continuous strands. The cloth is formed by interweaving one set of threads, which run the length of the piece, with another set, which extends

JOHN KAY
Inventor of the flying shuttle.

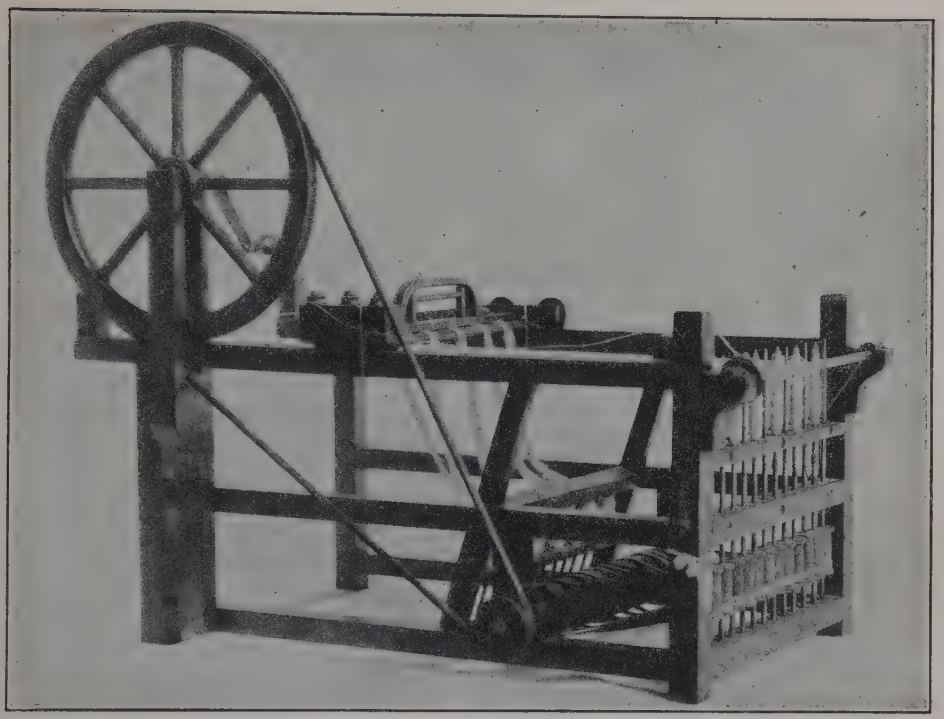
across from side to side. The loom is so made that a great number of lengthwise threads—every other one, in fact—can be alternately lifted and lowered above and below the other half. Then a little piece of wood, called the "shuttle," which carries inside of it a "bobbin," or spool of thread, shoots across the strands, paying out its own strand as it goes. After it has traveled once across the lengthwise strands a change is made, so that those that were above the others are now below them, and the shuttle returns, making a perfect weave. Then there is a frame, called the "batten," which drives the last thread thrown by the shuttle down hard against the woven part of the cloth.

JOHN KAY AND THE FLYING SHUTTLE

The first great step in the improvement of the loom came when John Kay of Colchester devised the flying shuttle, which, through the use of the handle and a spring, was jerked back and forth through the strands from side to side by the man who operated the loom. This did away with the need of one of the men who tended the loom; in other words, it made it possible for one man to do the work of two.

Every now and then we hear somebody mourning for the good old times when everybody was honest and respected the rights of everybody else to his own property. Englishmen of the seventeenth and eighteenth centuries were fond of referring to their country as the land of fair play. Yet, if the history of the inventors of this period is anything to judge by, the Englishmen of the eighteenth century had little or no regard for anything but their own selfish interests. Even if they had had no sense of fair play, they might have seen that they were doing great harm to the nation as a whole by refusing to allow the inventors, who were making life easier and more pleasant for the working class, to reap any reward from their inventions.

Trouble began with Kay's invention. The masters of the looms tried to get the invention without paying for it, they paid no attention to Kay's patents; they broke his spirit and his purse through the lawsuits that he had to bring against them. The weavers did everything they could to prevent the use of the shuttle. They could see nothing in it, except that it would



HARGREAVES' SPINNING JENNY
It is said that Hargreaves named this machine after his wife.

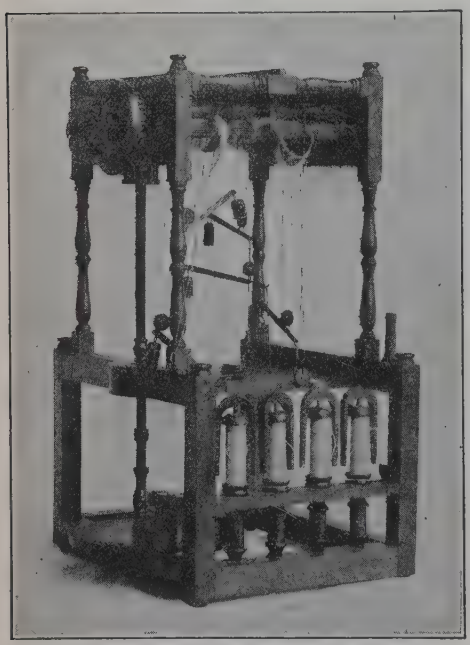
throw a number of men out of work. Kay went ahead with his inventions. Shortly afterwards he produced a rude loom that ran by water power instead of by hand. This further incensed the weavers, and a mob of them stormed his house, smashed his machines, and would have killed him had he not made his escape. He fled to France to die in poverty and wretchedness.

Such was England's treatment of one of her great benefactors. It will be recalled that, after Galileo, the great Italian, had been forced by the clergy publicly to deny his teachings that the world moved round the sun, he muttered softly to a friend, "It moves nevertheless." So, with Kay's shuttle; it continued to fly back and forth, and the first great step had been taken toward the development of the modern method of weaving.

JAMES HARGREAVES AND THE SPINNING JENNY

But further trouble arose. The flying shuttle made weaving so rapid that the supply of cotton threads could not keep pace with the demand. The fast-working weavers were forced to stop and wait, because the spinners could not keep up with them. Among the many who worked on the problem of how to speed up the spinning process was an ingenious weaver named James Hargreaves. He had already shown his skill by the invention of a carding process, by which the cotton was combed out and cleaned to get it ready for the spinning. For some time he worked on a method of spinning two threads at once, but if they were both spun in a horizontal position, there was difficulty in keeping them from getting entangled, and he had to give

it up. One day one of his children happened to upset a spinning wheel. With the machine lying on its side it kept turning, but the spindle was standing upright instead of horizontal. Instantly he saw that if he could place several spindles in this position side by side with a horizontal wheel, he could avoid the entanglement which had spoiled his earlier plan. Not long afterwards, in 1767, he had made a frame which spun eight threads at once. This was the celebrated "spinning jenny," named, it is said, after Hargreaves' wife.



ARKWRIGHT'S SPINNING FRAME

The Hargreaves family began to produce great quantities of thread, and the secret was soon out. Again we hear of the powerlessness of the law and the blind senselessness of human greed. A mob of spinners treated Hargreaves exactly as Kay had been treated thirty years before. They broke into his house, smashed the jenny, and forced Hargreaves to flee for his life to Nottingham. The owners of looms combined against him. He took out a patent, but they shamelessly used the machine without paying him a cent for it, knowing that he was friendless and too poor to fight them in the courts. He followed in the trail of Kay, and, ten years after he had made his famous invention, he died unknown and penniless.

RICHARD ARKWRIGHT AND THE SPINNING FRAME

The next inventor is Richard Arkwright, sprung, like Hargreaves and Kay, from the poorest of the poor. The youngest of thirteen children, he had been forced to learn the trade of barber. He must have been a bright and ambitious young man, for he was not content to make his living shaving workingmen at a penny a shave. It was the day when powdered wigs were much in vogue, and hair for making them was in great demand. Arkwright became a hair-buyer and wig-maker. He had hit upon some method of coloring the hair, which was better than the average, and he soon had a good trade.

There is a story that, in his traveling around through Lancashire, he stopped one night at the home of James Hargreaves, where he saw for the first time the celebrated spinning jenny. But no one is sure that the story is true. Hargreaves' spinning jenny was now turning out such quantities that it had offset Kay's flying shuttle, and now the weavers could no longer keep up with the production of the spinners. One of the great difficulties in weaving came from the fact that it seemed impossible to spin cotton yarn of sufficient strength to make a good weft. It must be explained that the threads which ran lengthwise in the cloth are called the "warp," while those which run across the other way are called either "weft" or "woof." The weaver

had difficulty in getting sufficient weft for his day's work, and it was not uncommon for such a man to have to call on four or five spinners the first thing in the morning, in order to gather in enough weft for his morning's work.

Meanwhile Richard Arkwright had been experimenting with a machine to produce perpetual motion. Not being a mechanic himself, he hired a clockmaker named Kay (no relation of John, the inventor of the flying shuttle, so far as we can learn); but when his attention was called to the need for a machine to spin the kind of weft that the looms needed so badly, he dropped his experiments with perpetual motion, and went to work, with Kay's help, to build a machine for spinning cotton thread.

When his first model was finished, he thought of the fate of Kay and Hargreaves, and would not give his machine to the weavers of Lancashire. His good fortune at this time brought him into contact with a firm of stocking makers, Messrs. Need and Strutt. He was able to prove to them that his invention was a valuable one, and they entered into partnership with him. He took out the patent for his spinning frame on January 5, 1769. This was a memorable day in the history of industry, for on the same date there was granted a young man named James Watt the basic patent on the steam engine.

Arkwright's spinning frame was a combination of carder and spinner. It is said that he got the idea of it by watching a red-hot iron drawn out into wire through a pair of rollers. The basis of his machine was that the cotton had to pass through two sets of rollers, one revolving faster than the other.

Immediately there came fights with the greedy manufacturers. Some of the men who were trying to profit by the new invention bribed Arkwright's mechanic, Kay, to leave him, and before long there was a serious lawsuit, in which certain of the manufacturers tried to prove, through Kay, that Arkwright had stolen his ideas from another man named Highs. But Arkwright was made of different stuff from John Kay and James Hargreaves. His fighting blood rose to do battle with his enemies, and in the end he beat them, thanks to the help of his well-to-do partners. He became wealthy, was elected sheriff of his county, and was knighted by King George III. The rival manufacturers tried to break him, but he beat them with their own weapons, and came out triumphant from the battle.

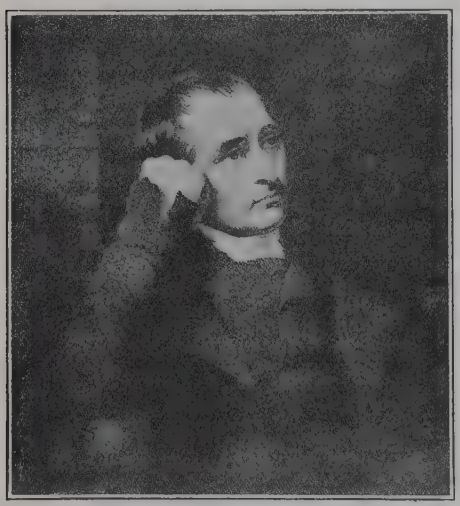
The yarn that was turned out by Hargreaves' jenny and Arkwright's frame was much better than the old stuff that was turned out by hand; but still it was coarse and knotty. There was still great need for improvement, if the English spinners and weavers were to turn out goods to compete with the fine muslins that were imported from India.

SAMUEL CROMPTON AND THE SPINNING MULE

About ten years after Arkwright had taken out his first patent, there appeared upon the market a new machine, the invention of a young man named Samuel Crompton. Crompton's father had died young; but his mother, who was a woman of great courage and good sense, insisted that her children should have a good education. A weaver herself, she was noted for the excellent work which she turned out. Her boys were forced to spin the yarn which the mother wove, and little Samuel, brightest of the family, was irritated by the constant trouble of mending the broken threads where poor spinning had produced knots and imperfections. For years he worked on

a contrivance which should unite the best features of Hargreaves' spinning jenny and Arkwright's frame, until at last he produced something which he himself named the "spinning mule."

The idea was that just as the mule combined the good points of the horse and the donkey, so his machine united the best features of the jenny and the frame. Just about the time that Crompton had finished his work, a mob of weavers and spinners went around smashing every machine that



SAMUEL CROMPTON
Inventor of the spinning mule.

they could find. To save his precious mule, Crompton took it apart and hid it away in the attic of the old hall which he used as a work shop. After the riot had subsided, he dared to bring it out again, and began to use it.

The fine yarn that it produced created much surprise, and brought great fame to the inventor. Crompton, like John Kay and Hargreaves, was a simple-minded man, honest himself, and believing others to be the same. A man who pretended to be his friend advised him to sell his invention to the manufacturers. These people signed their names to a paper, subscribing certain sums, which they promised to pay Crompton if he would allow them to use the mule. When it came time for them to pay up, many of them were so devoid of honesty that they refused to pay even the small sums that they had subscribed.

He had one bitter experience after another. As soon as he taught workmen how to run the mule, they were lured away from him. The manufacturers, who had no right to do so, took out a patent on his machine and when he tried to produce wool himself, he was beaten in competition by large manufacturers who used his own machines. Bad luck seemed to follow him, for a moment after the Chancellor of the Exchequer, Mr. Perceval, announced that he was going to ask Parliament to appropriate $100,000 to reward Crompton for his invention, an enemy of Perceval's, who had been lying in wait to kill him, shot down the statesman in cold blood, and the project died with him.

At this time Crompton's machine was such an improvement over those of Hargreaves and Arkwright that more than twelve times as many of the mules were in use as of Arkwright's frame, which was far in excess of the number of spinning jennies which were in operation. Parliament finally did give him $25,000; but this was all used up in paying off the debts which had been caused by his previous bad luck in business. When, in his old age, there came a vacancy as inspector of factories in Bolton, and he applied for it to save himself from starvation, he was turned down in favor of a young man with political influence whose father had been one of the secretaries of state, but who did not know a mule from a jenny. Thus, in poverty and obscurity, died the fourth of the men who have made England a great industrial nation.

THE POET-CLERGYMAN WHO INVENTED THE POWER LOOM

So far, the men of whom we have told have been children of common people—uneducated, and either ignorant or self-taught. The man that we shall consider next was a college graduate, a clergyman, a scholar and a poet. He had never taken the slightest interest in machines or their construction. He had never seen a loom at work. He had preached his sermons, made his pastoral calls, and spent his spare time writing verses and magazine articles on classical subjects. It so happened that, in the summer of 1784, a group of gentlemen were gathered at dinner at the home of a country squire, near Matlock in Derbyshire. Among the number was the Reverend Edmund Cartwright. Among the other guests were two manufacturers of cotton, who were bitterly complaining because Arkwright and Hargreaves were inventing machines which turned out yarn in such quantities that the weavers could not keep up with them. One man predicted that the result would be that great quantities of yarn would be imported to continental Europe, to be worked up by foreign weavers. At this point Rev. Cartwright remarked that probably the shrewd Mr. Arkwright would next produce a device which would weave by machinery. The practical manufacturers flouted the idea, pointing out that so complex a process as weaving could never be done by any machine. Dr. Cartwright replied that no one could foretell what the future had in store, for a few years ago people would have said that it was impossible for a machine to do what Arkwright's frame was now doing, and he saw no reason why some man should not produce a "weaving johnny" just as well as a spinning jenny, the established invention of James Hargreaves.

This chance conversation gave rise to another of the world's great inventions; for, stung by the scoffing of the manufacturers, the poet-clergyman went home and began to study the construction of a power loom. Strange as it may seem, he made his first machine without ever having visited a cotton mill to see how a loom was operated. He made such a visit, and was astonished at what he saw. He came home and changed his loom greatly, to conform to methods already in use. By 1787 he was ready to exhibit his finished machine. It meant the end of his peace of mind, for the same fate pursued him that followed his predecessors. The goods that he made were maliciously damaged. His best workmen were taken away from him. The other manufacturers refused to honor his patent rights. When, after a series of discouragements and disasters, there came an order for 400 of his looms, a mob of rioting workmen set fire to the building where they were stored, and destroyed them.

DR. EDMUND CARTWRIGHT
The clergyman who invented the power loom.

THE MANY WAYS IN WHICH CARTWRIGHT SERVED MANKIND

Crompton, in his anger and disgust at the baseness of human nature, smashed into bits another invention, a carding machine which would have been of great help to the cotton industry; but the finer mind of Cartwright refused to give way to hatred of mankind. In spite of the fact that his money was gone, he kept on serving the human race. He invented a bread-making machine and a rope-making machine; he made improvements on plows and carriages; he invented a fire extinguisher. He foresaw the use of ocean steamships and steam locomotives. He met and greatly aided the young American, Robert Fulton, in his efforts to secure recognition in Europe for his invention, the steamboat. It is an interesting thing to remember that Cartwright made a toy powerboat which was run by clockwork instead of by steam, and that this boat was made as a plaything for a boy who was later to be one of England's prime ministers, Lord John Russell.

When he was eighty years old, he went down to Dover for warm sea-bathing, and showed his bath man a method for pumping up the water, that saved him the services of two men a day. It was only a day or two before his death that he wrote a careful account of a new method that he had worked out for using Watt's steam engine.

Cartwright's power loom, however, is the thing for which he is chiefly remembered. An act of Parliament in 1808 gave him the sum of 10,000 pounds, which represented about one-fourth of the money that he had lost in his attempts to perfect his invention and put it upon the market. He died in comparative poverty—the fifth of the martyrs to the shortsightedness of the English people of his day.

JAMES WATT AND THE STEAM ENGINE

It will be recalled that January 5, 1769, saw two important patents granted. The one, as you have already heard, was given to Richard Arkwright for his spinning frame; the other was granted to young James Watt for a steam engine.

There are different stories afloat as to who first made use of the power of steam. It is said that the Marquis of Worcester, a gentleman who was imprisoned by King Charles I in the Tower of London, was the first to build a little engine which utilized the force of steam. The idea had come to him during his imprisonment, as he saw the lid of the teakettle in his cell lifted off bodily by the force of the vapor beneath it. However, Worcester's engine was a very rude and incomplete thing. About 1680 a Frenchman named Denis Papin built a steam engine equipped with a new device, the safety valve, and with a piston which fitted into its cylinder. Papin's name should be remembered among those of great inventors, for everywhere where power is used, men depend upon the principle which he worked out.

Meanwhile, there was greater need each day for some powerful machine. The coal mines in England were sinking deeper and deeper below the surface, and the big problem was to keep the shafts free from the water which constantly flowed into them from underground. There finally came a poor blacksmith of Dartmouth, Thomas Newcomen, who produced in 1705 an engine which drove up a piston, by the force of steam, into a cylinder. A jet of cold water then condensed the steam, and formed a vacuum within the cylinder. The pressure of the atmosphere did the rest, forcing the piston rapidly downward. Thus, Newcomen's engine was

not a steam engine at all, but an air engine.

A boy named Humphrey Potter, who was tending one of Newcomen's engines, through using certain strings and latches, made a Newcomen engine open and shut its own valves. This device more than doubled the speed of the engine. It made sixteen strokes a minute, where before this time, it had made but eight.

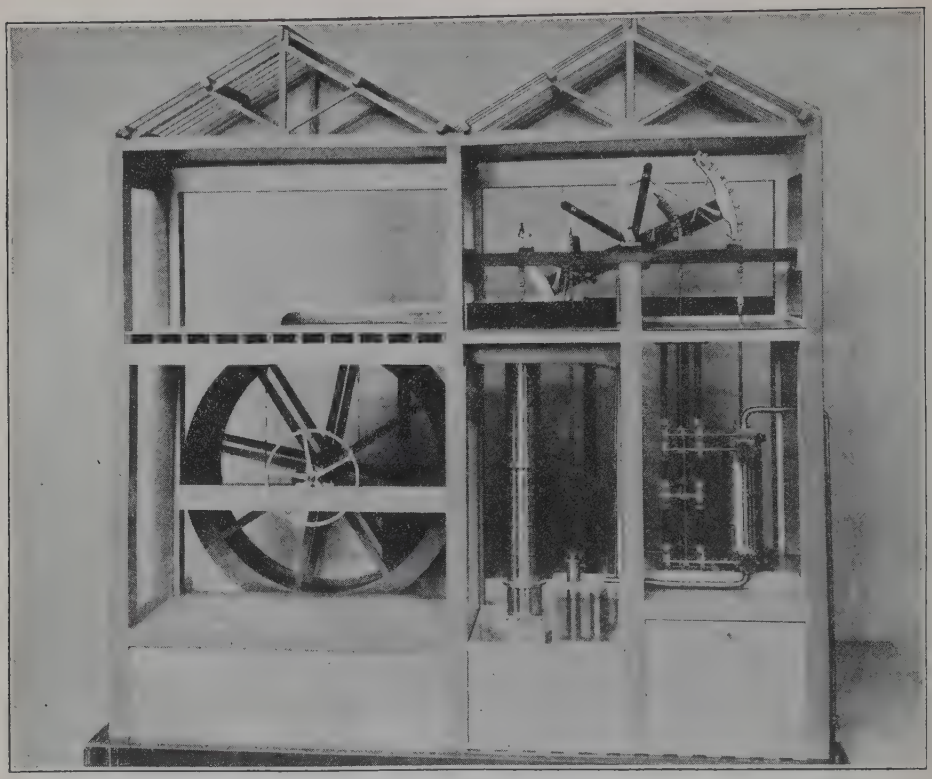
But the steam engine itself had not yet been invented. It remained for a Glasgow instrument maker, James Watt, to produce the first machine in which the piston actually was driven to do the work by the force of steam itself. James Watt was a great reader as a boy. He studied astronomy, physics and optics. He learned to make spectacles and quadrants, instruments for measuring altitudes. He also turned out violins, flutes and other musical instruments. He even constructed a pipe organ. It was in the winter of 1764 that there was brought to him for repair one of Newcomen's engines. The clumsy machine did not appeal to him. He saw at once that great improvements in it were possible. For ten years he worked on the problem, taking out his first patent, as has been said, in 1769. His great contribution was that he provided a chamber near to the cylinder in which the piston worked, by which steam alternately was introduced, first at one end and then at the other, of the cylinder, and forced the piston by its own power, and not by the weight of the air, backward and forward at a rapid rate. The first machines worked in a jerky and spasmodic fashion. The principle was correct, but minor details had to be perfected. Other inventions were necessary to make it work smoothly. Watt himself made the most important one, the ball governor, which automatically shut off the supply of steam when the speed of the engine grew too great.

In the midst of his worry, he received news that some rascals had stolen his idea and were selling his great invention in London. He was just on the point of giving up the whole thing, when he was lucky enough to come in contact with Matthew Boulton, one of the leading manufacturers of Birmingham. Boulton bought a two-thirds interest in Watt's invention, and

JAMES WATT

furnished capital to go on with the manufacture of steam engines. With Mr. Boulton looking after the money for the firm, and with Watt perfecting his machines, prosperity came to them. All over England the mines discarded the clumsy Newcomen engine, finding that Watt's machine did five times as much work for the same money. Our old friend, Dr. Edmund Cartwright, came to his rescue also with the invention of the piston rings, which prevented the leaking of the steam, and allowed a higher pressure than Watt's first engine could produce.

At last Watt was able to retire. His busy brain, however, could not rest. In order to keep himself occupied, he

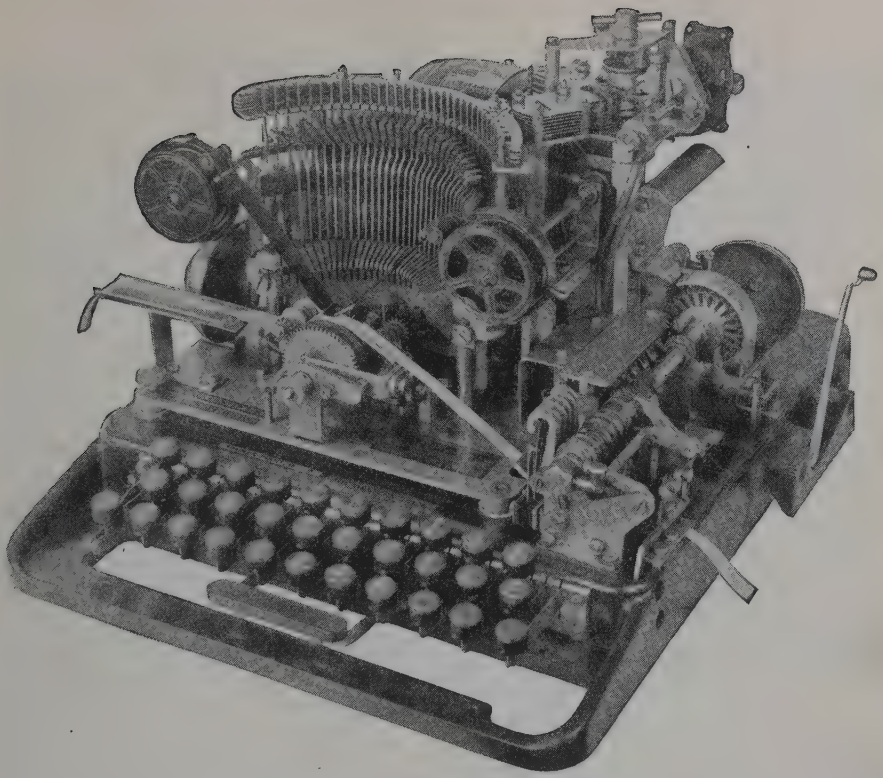


WATT'S STEAM ENGINE
A model of James Watt's first steam engine.

began the study of the old Anglo-Saxon language; and before his death, in 1819, he became one of the greatest authorities on this earliest of the English tongues.

Such is the story of the men who transformed Great Britain. One is tempted to say that Great Britain hardly deserved citizens like these, for the treatment accorded them was far from their deserts. Yet the spirit of invention drives certain men as the spirit of discovery has led others; and just as Columbus, Magellan, Marquette, LaSalle and Drake could not rest nor be contented while unknown lands beckoned them onward, so Arkwright, Watt, Crompton and Cartwright were driven by a force within them to devise and invent, that all mankind might be benefited by their labors. The world rewarded none of them as they deserved, with the single exception of Arkwright, and this was due to his fighting, indomitable spirit. A weaker man would have gone under, as some of the others did. But their fame will live; and wherever a piston drives or a wheel turns or a loom weaves, one will think of the time when the Industrial Revolution created a new world of manufacture.

Illustrations on Pages 373, 374, 379, 380 from U. S. National Museum; those on Pages 371, 372, 376, 377 from *The Story of Textiles.*



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AUTOMATIC TELEGRAPH TYPEWRITER

This telegraph printer is a modern sending and receiving unit. It is driven by a small motor and is so arranged that when a key is struck signals are sent over the line and at the receiving point the corresponding letter is printed on an identical unit. The line receiving magnet is shown at the upper right of the picture. These instruments are located in thousands of telegraph offices and are connected by direct wires with similar printers in the offices of thousands of large business firms.

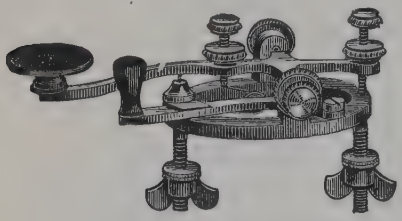
TELEGRAPH, TELEPHONE AND CABLE

NOBODY can say what electricity really is. It is not matter; it cannot be seen, though its effects can; it cannot be smelled or tasted. But though we do not know what it is, we know how to bring it into use, how to create or excite it and how to harness it.

THE TELEGRAPH

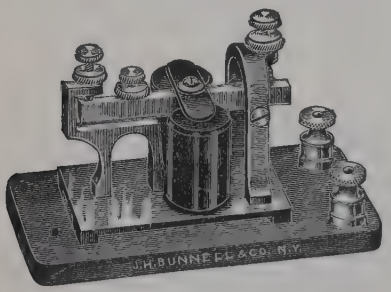
Let us explain the simplest way of telegraphing from Chicago to New Orleans. In the telegraph office is a battery from which electricity can be sent along the wires. The wires coil around a piece of iron, and so long as the current of electricity is passing through the coil the iron acts as an electro-magnet and draws other iron to it. The moment the current ceases, the iron is no longer a magnet. When sending electricity through the coil, we are magnetizing the coil. The current flows along the wire, and while it is going the circuit is said to be closed; when the current stops, the circuit is broken. While we have been explaining these points we have handed the operator our telegram for New Orleans.

Before him there is a little lever with a knob at the end. This lever is called a key. While that key is at rest, the



A telegraph key used to send telegrams

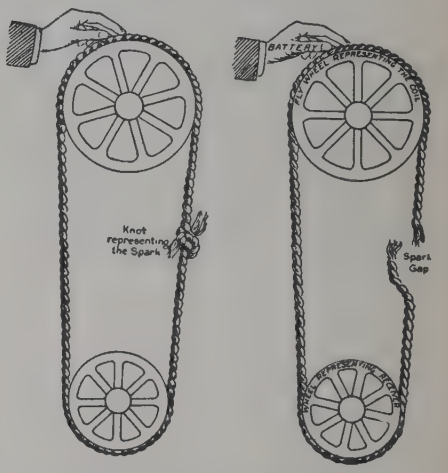
circuit is broken. The moment he presses it down, the circuit is closed, and the current races along the telegraph wire. He taps away at his key and the message flies over the wires to be written down at the New Orleans telegraph office. How is it done? New Orleans is the receiving end. Well, there, at the end of the wire, they have an electro-magnet made as we have seen, of wire and iron. A current comes from Chicago. It enters the office by the wire. It passes through the coil and makes the iron magnetic. The magnet attracts towards itself a little metal bar working on a lever, and every time this bar comes down to-



A sounder used to receive messages

wards the magnet, the end of it taps upon a small screw; then when it goes up again it taps on another screw. Each tap that it makes corresponds with something that the clerk in Chicago has done at his end of the wire.

The Chicago clerk, as we have seen, presses down a key. That key, when at rest, has its knob raised in the air. There is a wire attached to the key. Now, when the key is pressed down, its under side touches another wire. The pressing down of the key joins these two wires together. That closes the circuit. The joining of the two wires instantly causes a current of electricity to flow from the Chicago battery over the wire to New Orleans. The instant that the key is allowed to



This diagram explains the uses of the battery, coil, and wires in the sending of a telegram. The hand stands for the battery, which provides the energy. The big wheel represents the coil, which regulates the electric current to flow as we want it. The rope represents the flow of the current, conveying the energy to the small wheel, which stands for the receiving end. The knot represents the closed key spark, which ties the ends of the rope, or current, together, as it were. When the knot is tied, the circuit is closed. When the knot is untied, the circuit is broken. It is the rapid tying and breaking of the key knot that produces the electric waves.

rise from the wire underneath it, the circuit is broken and the current is stopped. While the current is flowing, the coil and iron at New Orleans become a magnet, that draws towards itself the small metal bar.

Clever men thought out a way of making this of use. They arranged that certain pressures by the sending key should stand for certain letters. We have only to agree once for all that a certain sign shall stand for a

Western Union Photo

HOW MOST LONG DISTANCE TELEGRAMS ARE HANDLED

As many as eight messages are sent over one wire in both directions at the same time by use of the multiplex printing telegraph. The operator is shown sending a telegram by this method. As she types, her machine perforates a tape which then passes through a transmitter in which five contacts are controlled by five rows of holes in the tape. The five contacts send impulses through as many segments of the distributing mechanism, which rapidly assigns the wire in turn among several operators at as many multiplex machines. A similar distributing mechanism in the distant city unscrambles the messages which are then printed on the tape of multiplex printers.

certain thing, and then we know what it means. And that is how we got the telegraph's A, B, C. A very short pressure of the key in Chicago gives two taps at New Orleans, one very quickly after the other, and a longer pressure gives two taps, but with a longer interval between them. These tappings correspond with the dots and dashes of the Morse alphabet. When we send our telegram from Chicago to New Orleans, the telegraph operator turns the letters which we have written into telegraphic letters. Each tap is registered at New Orleans instantly it is made. With each pressure upon the key the circuit is closed, and the current flies for a certain length of time, signifying a sign which means part of a letter. Each time the key is at rest in its ordinary position, the current ceases to flow.

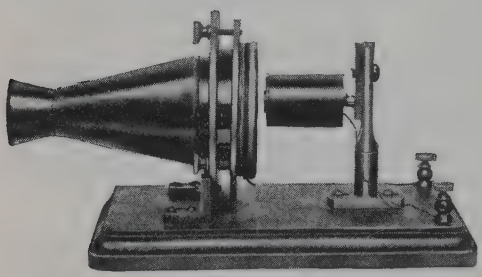
Improvements in Telegraphing

Our story thus far has told of the simple form of sending messages by the telegraph. But now it is not usually a matter of dots and dashes. The electric printing telegraph, after nearly a century of experimentation and development, has become such a commercial success that most of the great work of telegraphing is done with this instrument. Automatic telegraphy has, in most places, superseded the Morse code and as an ordinary thing, operators in Chicago simply press typewriter keys and the telegraphic communication is automatically printed in New Orleans or New York, ready for delivery. Every big newspaper has this sort of equipment today.

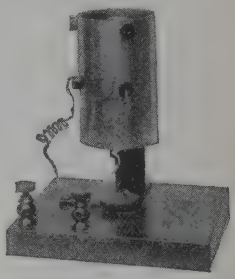
Furthermore, through the use of many currents of electricity flowing through the same wire, as many as

eight machines may be attached to each end of the wire. By diverting the electric currents that flow over the wire into different channels, all eight machines (four sending and four receiving) may be operated at the same time, maintaining a total speed of as high as a thousand messages per hour.

We do not find the elaborate instruments in small telegraph offices, many railroads, and small stations generally. There the Morse system of key and sounder is still in use and it is doubted by authorities that this simpler system will ever be wholly supplanted by the complex rapid apparatus described above.



Transmitter



Receiver

PROFESSOR BELL'S CENTENNIAL TRANSMITTER AND RECEIVER

On this instrument Dr. Bell was granted the original patent in 1876 for the speaking telephone. It was exhibited at the Centennial Exposition at Philadelphia in 1876.

THE PRINCIPLE OF THE TELEPHONE

The telephone wire and the principle of telephoning are similar to the telegraph, but here a small disc of steel is used in gathering the sound waves of the human voice and in starting them over the wire to a similar disc or diaphragm, which gathers the sounds and carries them through a receiving instrument to the ear. It was in 1875 that Professor Bell (see Story of Bell in Vol. VI) discovered this principle and from the early use of the telephone for very short distances we have seen the long distance call become a regular part of the business day.

MESSAGES UNDER THE SEA

If we have relatives away over the sea to whom we may wish to telegraph, we can reach them by a message carried by electricity under the sea. There are over 325,000 miles of these submarine cables in use, so that we can exchange messages with England, Panama, Australia, New Zealand, India, China, and every other civilized country. The principle is the same as in the land telegraph, but the wires are different, and the rate of telegraphing is slower, as the current passing through these long wires is necessarily weaker, which makes the recording of the messages slower.

If the ordinary telegraph wires were used, the current would run off into the sea and be lost. So the wires have to be encased in gutta-percha, and bound round with tape and yarn, and brass, and tarred hemp, and over all are wound coils of stout wire, to protect the cable from the sea, and the rocks at the bottom of the ocean. For long distances, only one wire is placed inside the cable, but for shorter ones many can be used. More than one message can be sent over the cable at the same time.

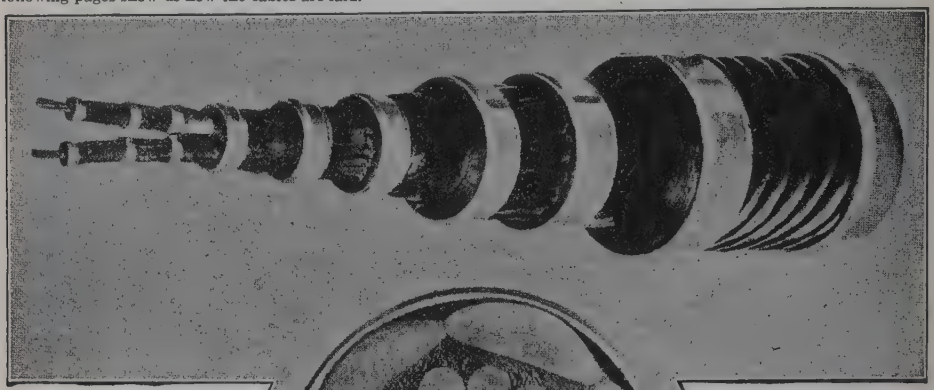
The early cable messages were sent by means of the mirror galvanometer, but later years have seen the development of the present siphon system. Ink siphoned from an ink-well is recorded by an electric pen on tape, which is actuated by clockwork. This pen responds to the most delicate magnetic attraction and writes very fine dots and dashes that are deciphered

THE VALLEYS, MOUNTAINS AND PLAINS AT THE BOTTOM OF THE ATLANTIC OCEAN

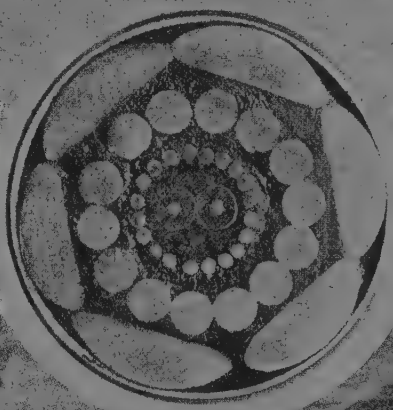
If all the water in the Atlantic Ocean could be drained away, the ocean-bed would look like some great stretch of country with deep valleys and mighty mountains These mountains would be the islands that now peep only above the waters. Stretching across the new country we should see the many cables that enable the Old World and the New to talk together.

THE ELECTRIC WIRE THAT RUNS UNDER THE SEA

One of the most wonderful things in the world is the way in which a thought can be flashed across the earth quicker than a messenger can carry a letter across a town. Every day messages are sent under the sea by means of electric cables lying along the ocean-bed. The text deals comprehensively with this great achievement of man and the pictures in the following pages show us how the cables are laid.



When we telegraph abroad, electricity carries our message through a thin wire under the sea. The wire would snap if it were not protected by coats of hemp yarns, and steel armor wires. A cable is always thickest at its shore end.



In the top picture we can see a piece of cable with the different layers cut away a little to show them clearly. It is the two thin wires at one end that carry the message. The picture in a circle shows a section cut across the same cable.

Marine plants and sea animals fasten and grow upon the cable at the bottom of the sea, as may be seen in this picture. Sometimes a cable is pulled to the surface with a large piece of coral growing all round it, or some big fish is mixed up with it. These were the greatest difficulties that the early layers of deep-sea cables had to fight against and learn how to overcome. Several years ago, something went wrong with a cable in the sea near Valparaiso, in South America. When it was hauled to the surface of the ocean, there was a dead whale with the cable coiled round its body. Such incidents are not uncommon, hence the need for great strength in the cable.

Western Union Photo

BRINGING THE CABLE IN TO THE CABLE STATION

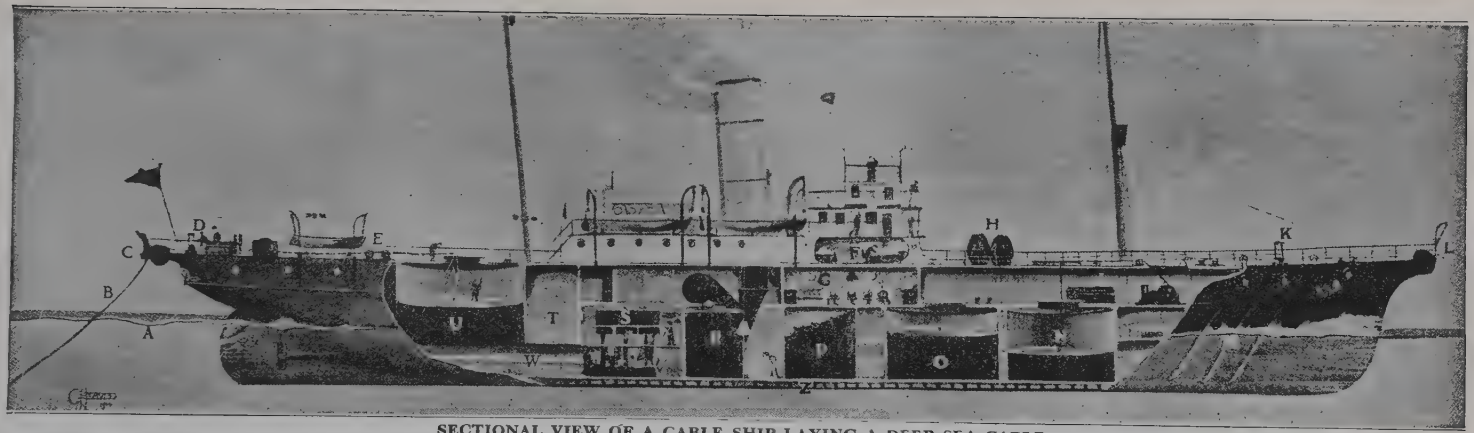
Here the cable is seen being floated ashore by means of barrels, and the end is being placed in a trench on shore.

by the receiving operator and written out as a message.

The speed at which cablegrams can travel is very great, though we have not yet the instruments to receive the messages quickly. A message has been sent under the ocean 8,000 miles in a single second. As it costs about twenty-five cents a word to cable across the Atlantic Ocean, codes are used by which one word may mean a dozen words or more. By this means time and money are saved.

Day by day we read in our newspapers of events that happened a few hours previously in remote parts of the world. The wonderful telegraph that runs along the bottom of the sea brings these messages to us.

Not many years ago an experiment was conducted at an exhibition in Chicago. A message was sent from a room, through the United States to Canada, from Canada to London, to Portugal, to Spain, to Egypt, to India, to Japan and on back to the same room from which it had started, but at another instrument. The message had traveled around the world in fifty minutes.



SECTIONAL VIEW OF A CABLE SHIP LAYING A DEEP-SEA CABLE

A. Water line; B. Cable; C Stern sheave; D. Dynamometer: E Retarding wheels; F Testing-Room; G. Dining-saloon; H. Buoys; I. Grapnel rope: K. Dynamometer; L. Bow sheave; M. Fenders; N. No. 1 cable tank; O. No. 2 cable tank; P. Bunkers; R. Boilers; S. Engines; T. Stores; U. No 3 cable tank; W. Shaft; Z. double bottom.

THREE COMMON CAUSES OF SUBMARINE CABLE BREAKAGE BY TRAWL, TIDE, AND ANCHOR

1. Cable house; 2. Waves and currents; 3. Ships' anchors and 4 and 5. Trawls, are constantly doing damage; 6. Water line· 7 End of cable temporarily attached to mark buoy; 8. Using grapnel to find broken cable

AMATEUR RADIO OPERATORS

These amateurs, or "hams," with transmitters shut off are listening for their call letters, coming perhaps from some place around on the other side of the world. The work of transmitting amateurs is full of human interest, and is a great factor in the spreading of international friendship.

RADIOTELEGRAPHY

IN radiotelegraphy we make use of electro-magnetic waves to transmit energy from one station to another

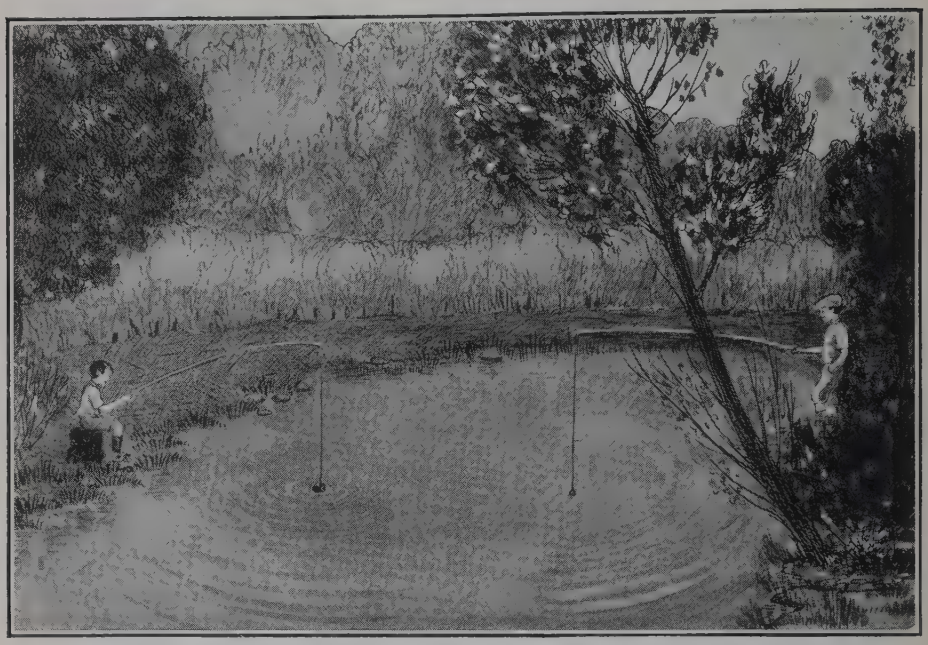
A boy can shake a floating chip on the far side of a pond by throwing a stone into the water and creating water waves which travel in widening circles until they reach the chip and cause it to bob up and down. In this case we can see the stone fall into the water, we can see the waves travel to the chip, and if we have good eyes we can see the chip move up and down.

If a railroad locomotive is at some distance, a mile perhaps, you may see a stream of steam start from the whistle; it may cease and disappear before you hear the sound of the whistle. You see the escaping steam and after some time, about five seconds in case the distance is a mile, you hear the whistle but you do not see the waves. The sound is carried from the vibrating whistle to your ears by means of air waves. You cannot see air but you have delicate instruments, your ears, which are affected by air waves.

In the case of the water or of the whistle you have a disturbance or vibration to start the waves, a medium to carry the waves, and an object at the receiving end which is set into vibration. The chip is the receiving object in the case of the water waves and the ear drum is the receiver in the case of the sound waves.

How radiotelegraphy uses ether waves

In radiotelegraphy we have the same. We have a sending station which causes electricity to vibrate or oscillate back and forth in the aerial. This is so arranged that the electricity will set up waves in the ether—a medium which we cannot see, feel, hear, smell or taste, but which trans-



A STUDY OF WAVES

No, the boys are not fishing. They are having a game of radiotelegraphy. The boy on the left has a chunk of wood on the end of his fish line and is making it bob up and down or vibrate. This makes waves on the water. These waves go to all parts of the swimming hole. The boy on the right has a light floater at the end of his line, which is made to vibrate by the waves. With his eyes shut he is trying to tell, when the waves come past by the faint jerk on the pole. If the boys have a code, that is an agreement that a certain number of waves mean certain things, they have a telegraph system—a wireless system. In fact, they have the essentials of any wireless system—a transmitting station where something vibrates or oscillates and sends out waves, a medium to carry the waves from one point to another and a receiving station or device to tell when the waves go past.

mits light waves and electro-magnetic waves. Then we must have a receiving station which is arranged so that the electric waves will cause electricity to vibrate or oscillate in the aerial and affect some device and cause a disturbance which we can see or hear.

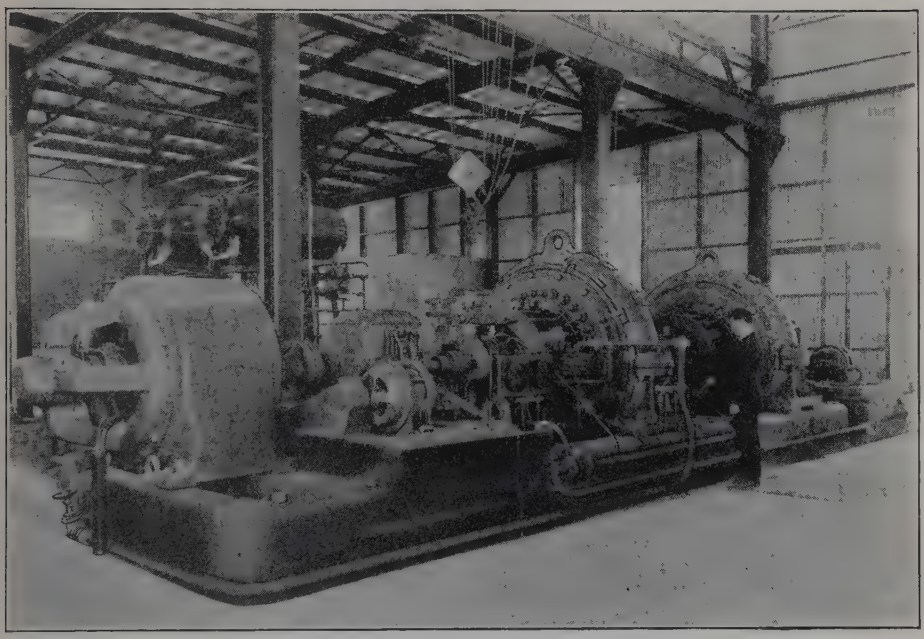
These ether waves pass out in all directions and can be detected by any one who has a sufficiently delicate receiving apparatus. The receiving apparatus may be on land a few miles from the sending station. It may be across the ocean. It may be on a ship on the ocean. It may be in an airship, balloon or airplane thousands of feet above the earth or sea. In some special cases the apparatus may be in a submarine on the bottom of the ocean, the signals being detected with apparent ease

Development in Radio

The advancement in radiotelegraphy and radiotelephony in the past few years has been marvelous. Now it is possible to communicate half way around the world. Of course, if you can communicate with any point on one hemisphere, you can communicate with all the world because the waves go east as well as west and north as well as south.

Long Distance Sending Stations and the Receipt of Their Messages

The long distance sending stations are elaborate power plants with high towers supporting antenna wires whose lengths are measured in miles. A

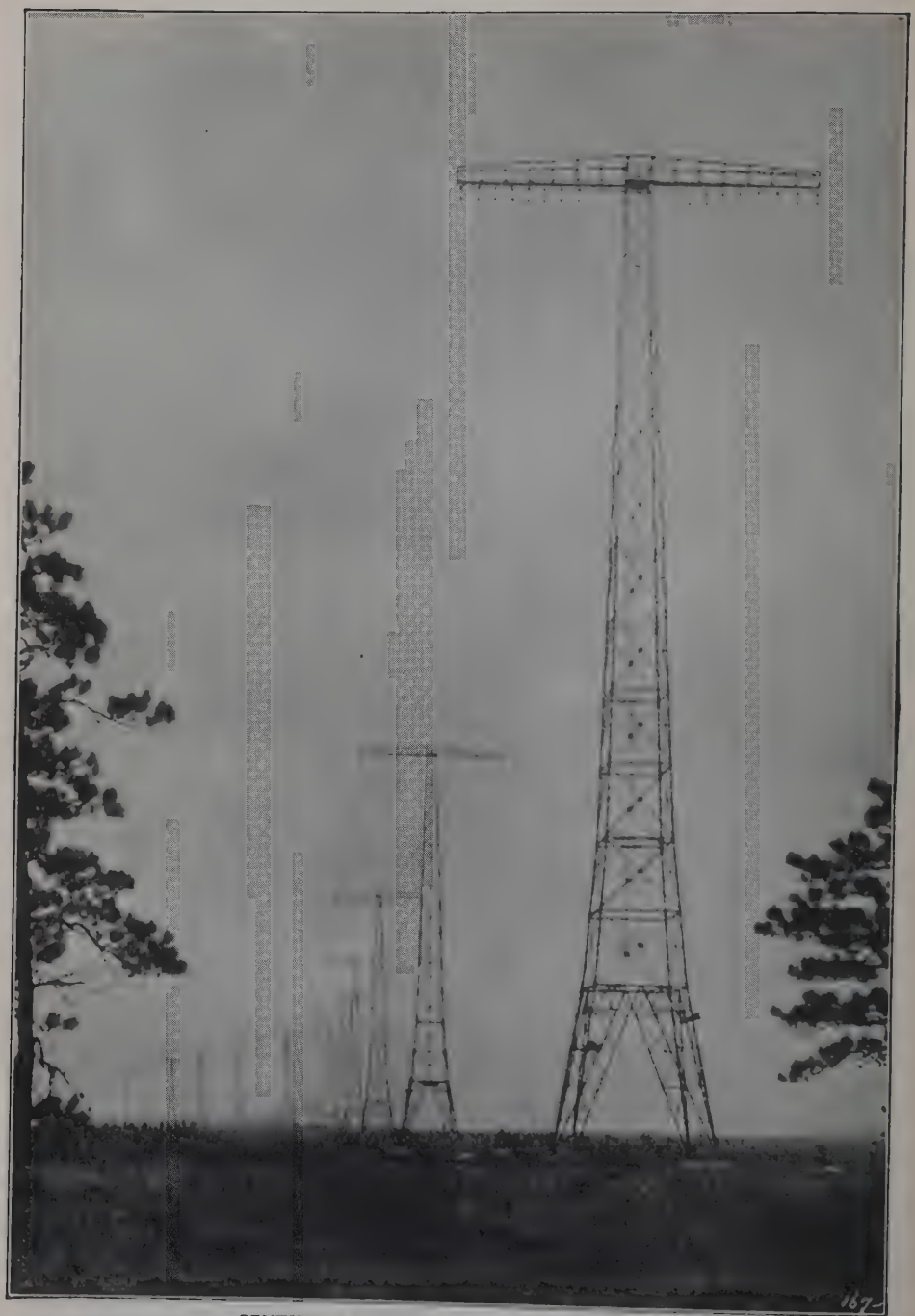


TWO HIGH FREQUENCY ALTERNATORS AT RADIO CENTRAL

These alternators are located in the first power house section at Radio Central. One is capable of furnishing a continuous output of 200 kilowatts at frequencies covering a wave length band from 15,800 to 20,000 meters. A sending speed of 100 words per minute is at present possible with the use of each transmitting unit at Radio Central. A combined capacity of 200 words per minute is possible with the two alternators.

RADIO CENTRAL OPERATING OFFICE

This scene is in the heart of New York City's downtown financial district. Here radiograms are sent to Europe and other places by way of the transmitters at the Rocky Point station on Long Island, ninety miles away, remotely controlled.



SENTINELS OF WORLD WIDE RADIOTELEGRAPHY

A view of the three-mile line of the first twelve towers at Radio Central designed for world wide radio communication which includes Europe, South America and the Far East. This super-station is situated at Rocky Point, Long Island, seventy miles from New York City. Eighteen hundred tons of structural steel were used to erect the first twelve towers. Each tower is 410 feet in height and the cross arm at the top is 150 feet long. The distance between two adjacent towers is 1,250 feet.

receiving station may be comparatively simple. Stations in France and Germany may be "heard" in America with apparatus which can be set on an ordinary table, the antenna being a few feet of wire stretched from the roof to a convenient tree. Or the antenna may be a few turns of wire wound on a frame a few inches in diameter. Wire attached to bed springs has served the purpose of an antenna at times.

The modern long distance stations are too complicated to attempt to describe in this book.

Damped and Undamped Waves

The long distance stations as well as the small stations use continuous or undamped waves. The older stations used damped waves.

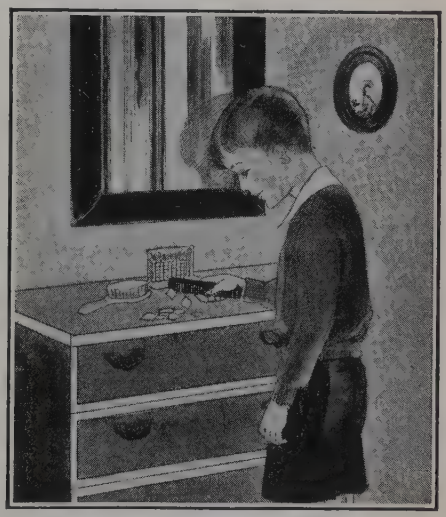
If a boy is swinging in a swing, as long as he "pumps" he swings to the same height. The to and fro motion is the same. When he quits pumping and "lets the cat die," the swing gradually slows down. The to and fro motion becomes smaller and smaller. The waves given out by a body vibrating, as in the first case where the boy is pumping, will give out continuous or undamped waves. Waves that are given out while the "cat is dying" are damped waves. The apparatus described first will be the simplest type of damped wave apparatus; then it will be easier to understand the modern continuous wave station.

An Experiment with a Rubber Comb

If, after combing your hair with a rubber comb on a frosty morning, you bring the comb near a bit of paper, the paper will be seen to move toward the comb. The comb is charged with negative (—) electricity, and we say the paper is attracted along the lines of force. The lines cannot be seen, but they run from the paper, table or ground to the negative (—) electricity on the comb. It can be shown that the paper or any near object is charged positively (+).

A Study of Oscillatory Charges

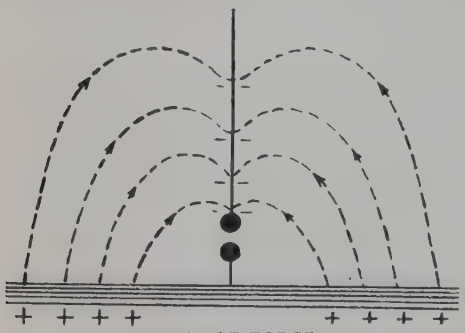
If we have a simple aerial or antenna wire, which consists of a long wire strung up a pole with two metal balls, one attached to the wire and the other attached to the ground, and if we charge the wire with negative electricity, the balls not touching, we have invisible lines of force running from the ground to the wire. If the charge becomes too great, there will be a spark between the balls. Now it has been found that when the spark occurs, the discharge is oscillatory. If a boy is in a swing and another boy pulls him back so as to lift him from the ground, when the boy in the swing is released, he starts toward the lowest point but he does



AN EXPERIMENT

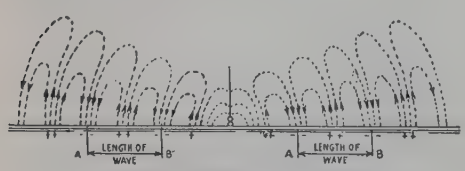
This boy is supposed to be combing his hair for school, but in reality he is playing with electricity. When he combs his hair with a rubber comb, the comb becomes charged with negative electricity, and small pieces of paper will jump to the comb. There are invisible lines of force running to the comb. We say the paper is attracted along the lines of force. If the comb could be charged and discharged a million times per second, these lines of force in traveling out from the comb would form electro-magnetic waves.

not stop there. He has so much motion that he starts up on the other side and then he swings back and forth, or he oscillates. The same is the case with the electricity. When the balls are charged, one positively (+) and the other negatively (−), they discharge until neither is charged, corresponding to the condition of a boy when he is at the lowest point in a swing. But the electricity does not stop; it continues to flow across the gap until the balls are charged opposite to the initial charges and then discharge back again or oscillate several times, perhaps 100 times. The discharge oscillates or swings back and forth until it stops the same as the boy in the swing when he "lets the cat die." To use the technical expression, we have a damped oscillation. The antenna wire will be first negative then positive and then negative for perhaps 100 times. The lines of force will be first toward and then from the antenna.



LINES OF FORCE

Here we have a drawing illustrating a simple antenna charged with negative electricity. The lines of force run to the negative electricity. Light bodies such as pieces of paper may be attracted enough to move along them. When they jump to the negative electricity they move along the lines of force.



OSCILLATORY CHARGES

When the antenna in the middle of the diagram is charged too much, a spark discharges from ball to ball. This discharge is oscillatory. The antenna is first negative then positive and then negative, changing at the rate of perhaps a million times per second. The lines of force are bent into loops and travel in all directions away from the antenna. The distance the wave travels during one complete oscillation is called a wave length. The lines of force cause positive charges at the points where they begin and negative charges at the points where they end. If there is another antenna as at the right of the drawing it will be charged first positively and negatively as the waves pass by it. If we have a delicate means of telling when this antenna is charged we can tell when the waves are going by. If the waves are sent out from the middle antenna for a short time we call that a dot. If for a longer time we call that a dash the same as in telegraphy. With the receiving apparatus we can tell when the waves are passing over in dots and dashes. If we know the International code we can read the message.

Since the lines of force are disturbances in the ether and since disturbances in the ether travel with the velocity of light, we have waves set up. These waves travel out into space, and since they end on a negative charge and start from a positive charge, a second antenna wire placed a hundred miles, perhaps a thousand miles away, will be charged alternately (+) and (−) as the lines of force, or waves, sweep past it. This will cause feeble currents of electricity to flow up and down the antenna wire with the same frequency as that of the sending station.

A high potential transformer and alternating current from the house lighting circuit is used to charge the balls. This transformer is the same in principle as the transformer used in lighting circuits except that the ratio of transformation in lighting circuits is from one or two thousand volts to 110 volts, while the high potential transformer ratio is from 110 volts to ten or a hundred thousand volts.

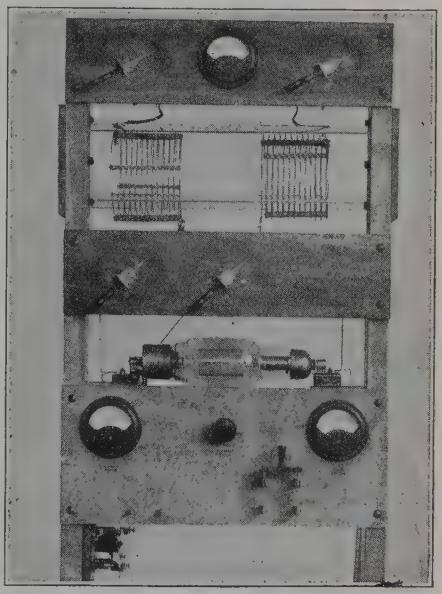
Attach the transformer to the balls and every time it sparks we have a set of oscillatory discharges. Perhaps the spark oscillates twenty-five times during $\frac{25}{1,000,000}$ of a second. As long as the battery key is held down we have fifty sparks per second but each spark is twenty-five oscillations. Thus for $\frac{25}{1,000,000}$ of a second we

have twenty-five oscillations and after $\frac{1}{50}$ of a second we have another set of twenty-five oscillations which lasts during $\frac{25}{1,000,000}$ of a second.

If one stops to figure the relative time intervals, he will notice that the time during which the electricity is not oscillating is perhaps a hundred times that during which it is oscillating. If a lazy boy wants to swing, he can do so in one of two ways. He may get a big push from his father in the morning as he goes to work, another big push at noon, and another big push when he comes home from work in the evening. Or, the boy may prevail upon his little sister to swing him continuously during the day. In the first case, we have the push and the dying down. The relative time intervals between pushes is about the same as in the case of the damped oscillations of the electricity in the old-fashioned transmitters. The lazy boy will get much more swinging during the day if he can get his sister to push him continuously. He does not swing as high as when his father pushes him, but he swings all the time.

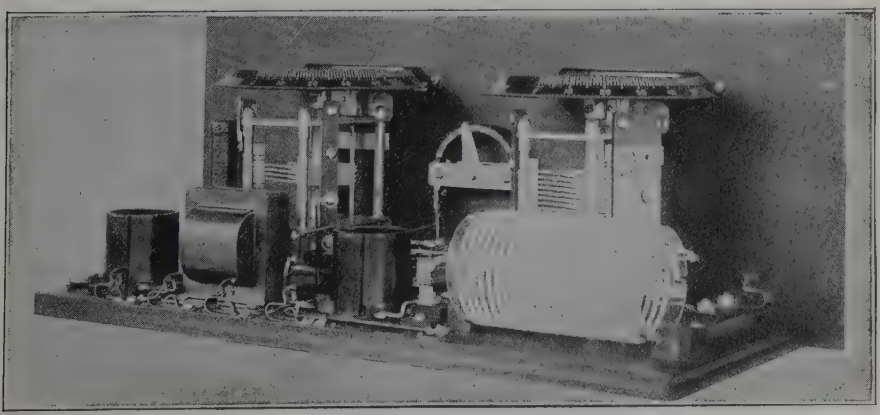
THE CONTINUOUS TRANSMITTER

The continuous wave transmitter is one in which the electricity vibrates all the time. It is not as noisy or "spluttery" as the damped wave apparatus, but it is always working, not resting most of the time. Since the vacuum tube has come into use, it has been found that a very simple and efficient continuous wave transmitter using vacuum tubes can be



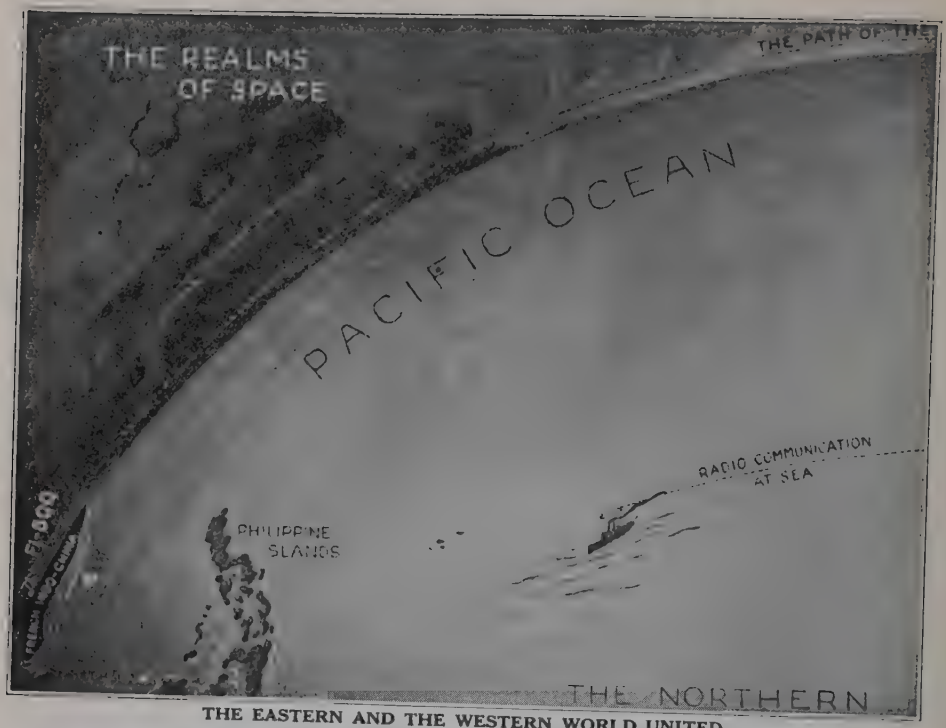
AMATEUR SENDING SET

Designed by John L. Reinartz of Reinartz circuit fame, and operated by him on the *Bowdoin* during the 1925 MacMillan expedition to Greenland.

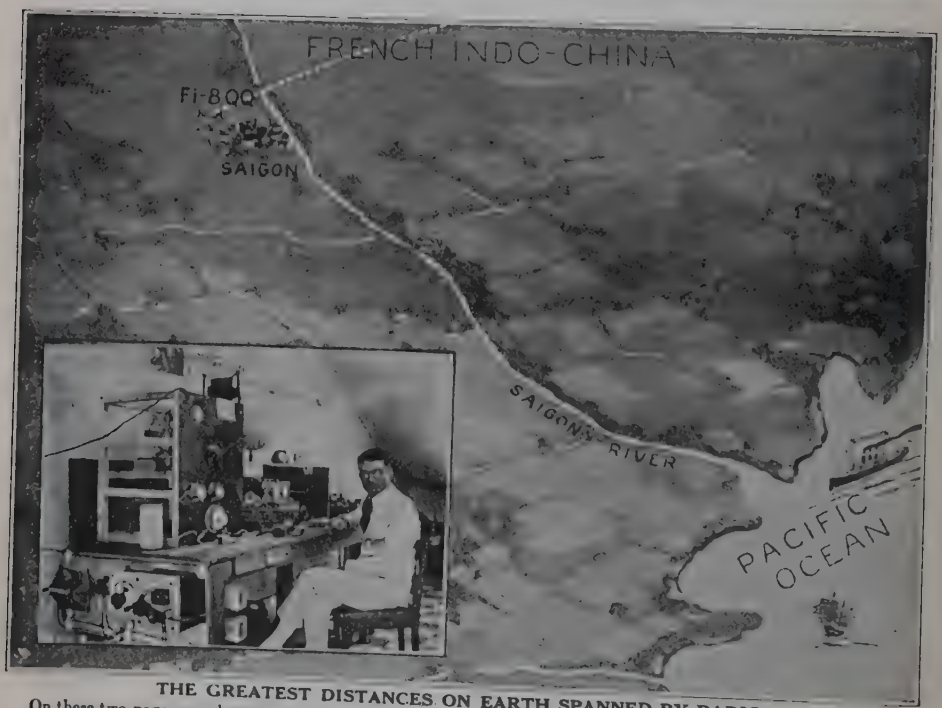


A SHORT WAVE RECEIVER

The coil is made of a few turns of heavy wire and is mounted on glass. This is to reduce the losses in the coil.

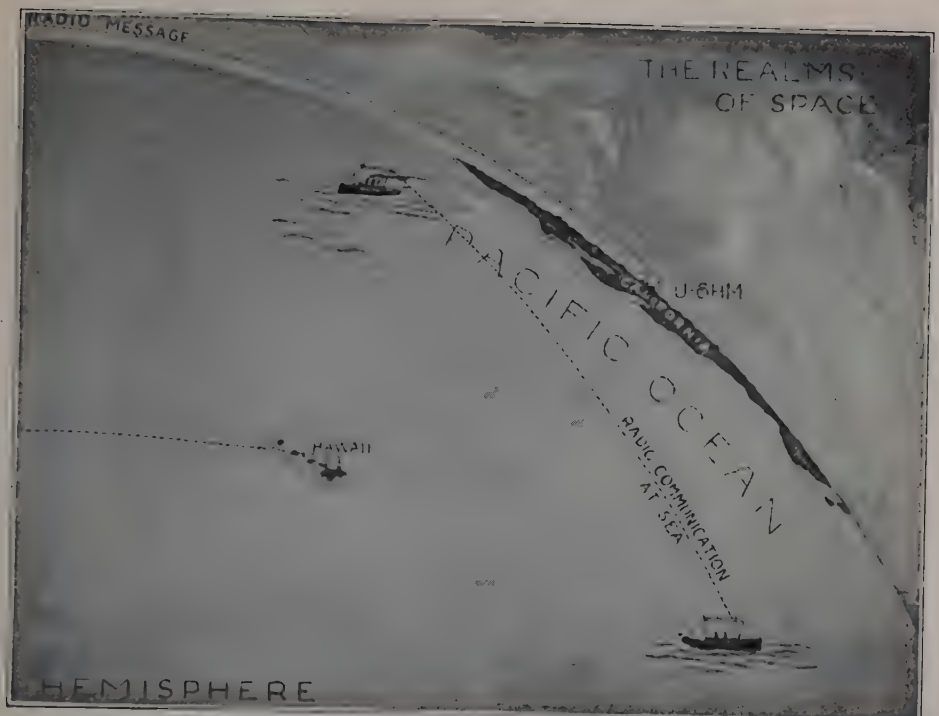


THE EASTERN AND THE WESTERN WORLD UNITED



THE GREATEST DISTANCES ON EARTH SPANNED BY RADIO

On these two pages are shown two amateur radio stations on opposite sides of the world in communication with each other; on this page the station at Saigon, French Indo-China, in Asia, operated by Richard Jamas. The photograph shows Mr. Jamas seated at his apparatus.



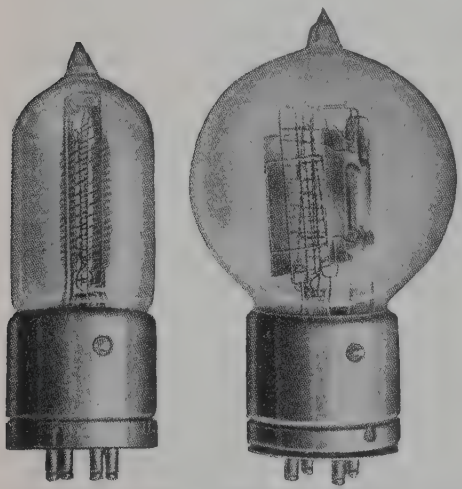
HEMISPHERES CONNECTED BY ELECTRO-MAGNETIC WAVES

THE PACIFIC BRIDGED BY AMATEUR RADIO OPERATORS

Over on the American side of the Pacific, in his station at Mt. Hamilton, California, is shown another amateur, Col. Clair Foster. He is listening for the call letters that come from beyond the wide expanse of the Pacific Ocean. The station shown was a temporary one.

made. The vacuum tube transmitters have practically displaced all old spark coil or "rock crusher" stations.

The coils are arranged so that the number of turns of wire which are used or the self induction of the coils can be changed. Likewise, the capacity of the condenser can be changed. The natural frequency of the circuit can be changed by changing either the inductance or the capacity of the



RECEIVING TUBE TRANSMITTING TUBE

The tubes originally manufactured by Western Electric Company. They are so made that the filament, grid and plate may easily be seen.

circuit. A boy in a short swing must pump oftener than if he were swinging in a long swing. He must pump at the right time. The frequency of the pumping must be the same as the frequency of the swing. If the boy could not change the frequency of the pumping then he would have to change the length of the ropes of the swing to make the swing of the proper length so that the frequency of the swing would correspond to the frequency of his pumping. When the frequency of the circuit (the swing) is the same as the frequency of the incoming waves (the pumping), the current (the height of swing) will be much larger than otherwise.

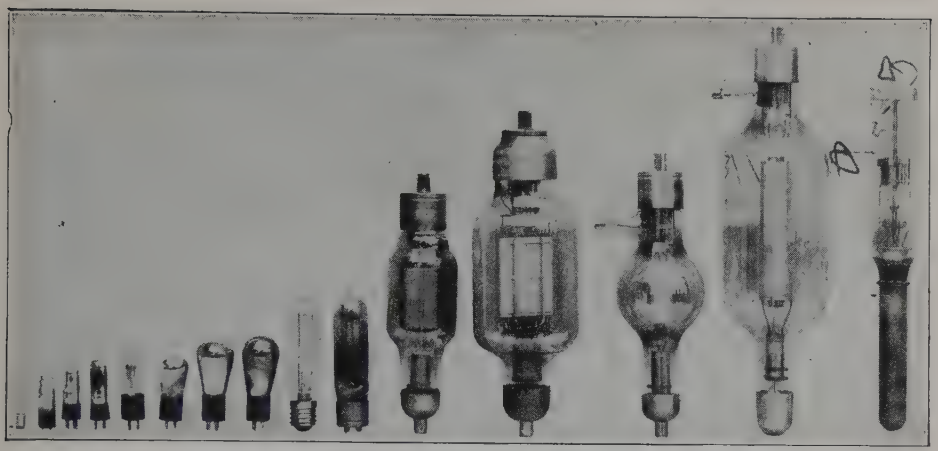
Tuning the circuit is changing the frequency or wave length by means of varying the capacity or by varying the inductance. By tuning the circuit and thus making the current due to waves of certain wave length large, and then by moving the secondary coil away from the primary coil the signals may be made weaker so that the only signal heard in the telephone is the one to whose wave length the coils have been tuned.

The wave length used by modern small stations is a few meters. Three hundred meters wave length corresponds to a frequency of 1,000,000 vibrations per second. Thirty meters is equivalent to 10,000,000 vibrations per second. This is so fast or the pitch is so high that our ears cannot hear the sound given off by the telephone when vibrating at this frequency.

Certain crystals when placed in the circuit have the property of conducting electricity in one direction only. A crystal receiver placed in the telephone circuit rectifies the current, makes the current flow in one direction, and makes it possible to hear a sound in the telephone whose pitch is due to the frequency of the spark, a frequency of fifty instead of a million per second.

The vacuum tube and what it does

Most modern receiving stations use vacuum tubes instead of crystals in the telephone circuit. The vacuum tube not only rectifies the current the same as the crystal but at the same time it amplifies or increases the current. The current through the telephone is increased and makes loud and clear signals which are too faint to be detected by the crystal receiver. A second tube can be used to amplify the current given off by the first tube



MODERN VACUUM TUBES *Courtesy General Electric Company*

The smallest one is a protective tube. The next five are the well known receiver tubes. The others are power tubes ranging up to the last one on the right which is a transmitting tube, in this instance a water tube; the lower part of the tube is copper, sealed directly to the glass of the upper part of the tube.

and a third tube will amplify that given off by the second. You will see then that exceedingly weak signals can be detected by means of several tubes. It is possible to amplify weak telephone currents so that a lamp will be lighted, the amplification being 10,000,000,000,000 times.

The vacuum tube has played a great part in the perfection of radiotelegraphy, radiotelephony and in long distance telephony.

The vacuum tube consists of a bulb, very much like an electric light bulb which has the air pumped out of it. It has a filament which is the same as the filament in an automobile lamp bulb. It has a plate of sheet metal placed on one or both sides of the filament and a grid or wire gauze placed between the filament and the plate. Terminals are brought out from the plate and grid. When an electric light filament* is hot, it gives off electrons or negative charges. A vacuum is a perfect insulator except for these electrons or carriers of negative electricity. Negative charges are attracted by a positively charged body. Thus if the plate is charged positively the electrons are attracted to it and a current flows from plate to filament.

But if the plate is charged negatively, the electrons are repelled back into the filament and there is no current. The current can flow in one direction only, or the tube acts as a rectifier. When the plate is positive and the grid is charged, the current from the plate is affected. The current is increased when the grid is positively charged and the plate current is decreased when the grid is negatively charged. The grid is connected to the wireless receiver. The potential of the grid oscillates in unison with the incoming waves. Thus the plate current fluctuates in the same manner but to a greater extent, causing the telephone in the plate circuit to give out louder sounds, corresponding to the dots and dashes. Larger tubes or power tubes can be used as oscillators to take the place of high frequency generators at the sending stations.

*Some metals such as thorium give off electrons when heated to a dull red heat. The modern tubes have thoriated filaments. The thorium is mixed with the tungsten of which the filament is made.

BEFORE THE MICROPHONE AT WGY

The microphone is supported by the pedestal in front of the man playing the violin. The studio may be miles from the transmitter; then the station is said to be operated by "remote control."

RADIOTELEPHONY

RADIOTELEPHONY is an outgrowth of radiotelegraphy. We first had the telegraph. Then came the telephone, by means of which we can talk to our friends at a distance, provided we have a wire connection.

After radiotelegraphy began to give promise of being successful, men began to say, "Why not talk to our friends through the ether, since we have the ether pervading all space?"

THE USE OF WAVES IN RADIO

In radiotelegraphy we make use of waves of certain frequency or wave length. These frequencies are very great—1,000,000 per second—while the frequency of the human voice is from 50 to 1,000 per second. Low frequency, or long wave radio, requires larger apparatus than high frequency or short wave. The length of the antenna of a sending station should be about one-fourth or one-sixth of the wave length. A wave length of 300 meters (1,000,000 vibrations per second) requires an antenna of about 100 feet or 150 feet in length. One thousand vibrations per second (wave length 300,000 meters or 300 kilometers) would require an antenna about 50 miles long at the sending station. This, of course, is out of the question, and besides every person's voice is not of the same frequency and the tone of the same person is constantly changing. In fact, the wave form of speech is very complicated.

Instead of trying to use the wave corresponding to the voice, a "carrier" wave is used. This carrier wave is a continuous or maintained wave of any convenient wave length, 300 meters

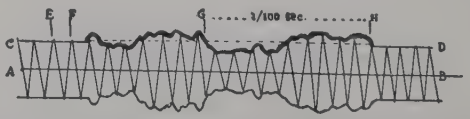


ILLUSTRATION OF A MODULATED CARRIER WAVE

The heavy black line is the complicated wave form of the human voice when making a simple sound such as *a* in father. The distance G to H represents 1-100 of a second. The zigzag line about the line, A B, as a center represents the carrier wave. The waves as drawn are 1000 to the second. There should be 1,000,000 to the second or 1000 between the distance, E F. It is impossible to draw so many lines without making a blur. When there is no one talking into the telephone transmitter these carrier waves will be of uniform height. When the transmitter is in use the apparatus is arranged so that the intensity or height of the carrier wave is changed to conform to the wave form of speech. If there were 1000 more waves drawn than are represented you can see that there would be wave crests to fit into every little crook and turn of the speech wave. When this carrier wave passes over the antenna and is received, the intensity of the current will vary in the same manner as the height of the crests of the carrier wave. When the current is rectified and sent through the telephone, the direct current will change in the same manner as the speech wave and the telephone will talk to us.

NBC Photo

MASTER CONTROL BOARD OF A LARGE BROADCASTING STATION

perhaps. The vibration frequency of this wave is so great that it produces no sound that can be heard in the telephone. This wave, when received by the receiving station and converted into oscillating current will produce a continuous current through the telephone.

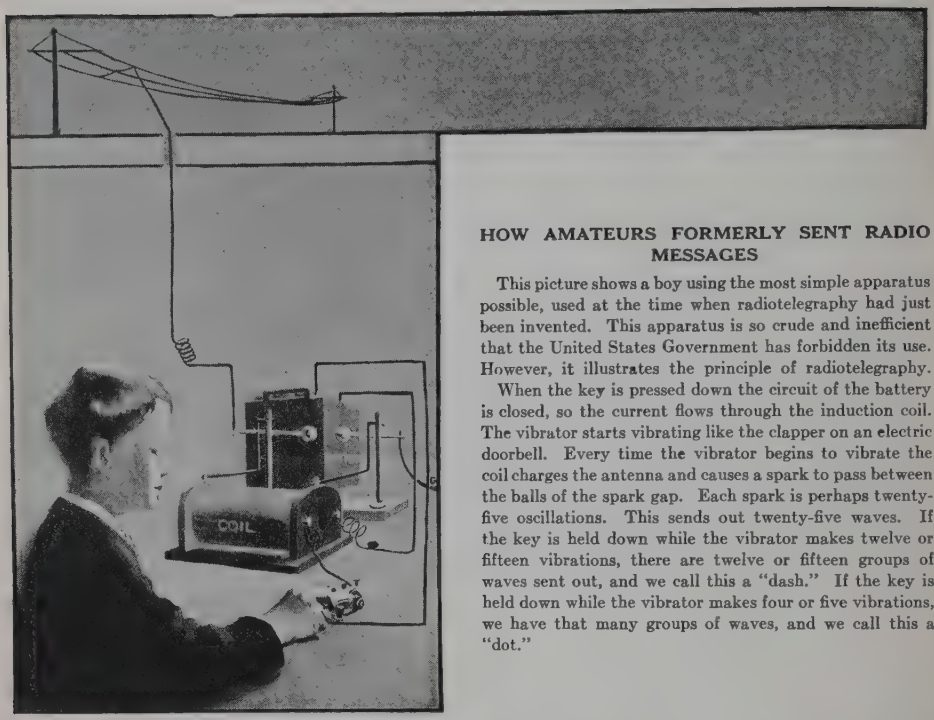
The sending device is arranged so that when one speaks into the telephone receiver the wave is "modulated," or the intensity or height of the wave is changed by the current produced by the telephone. When the modulated wave is received by the receiving station and the corresponding current is amplified and sent through a rectifier, or detector, the current instead of being continuous is fluctuating exactly in the same manner as the current from the telephone transmitter at the sending station, and of course when sent through a telephone receiver it produces the same sounds.*

THE VACUUM TUBE IN RADIOTELEPHONY

The vacuum tube (see Radiotelegraphy) has been a great help in perfecting the radiotelephone, or radiophone. The tube can be used as an oscillator to produce the sustained waves at the sending station. The tube's characteristics are such that they can be used to modulate the carrier waves when the telephone current is supplied to the grid. At the receiving station the tube acts as rectifier and amplifier at the same time. If the telephone is weak, so that the conversation is heard with difficulty, one or more extra tubes can be used as amplifiers so that every word is loud and distinct.

Conversations are possible with airplanes at a distance of many hundred

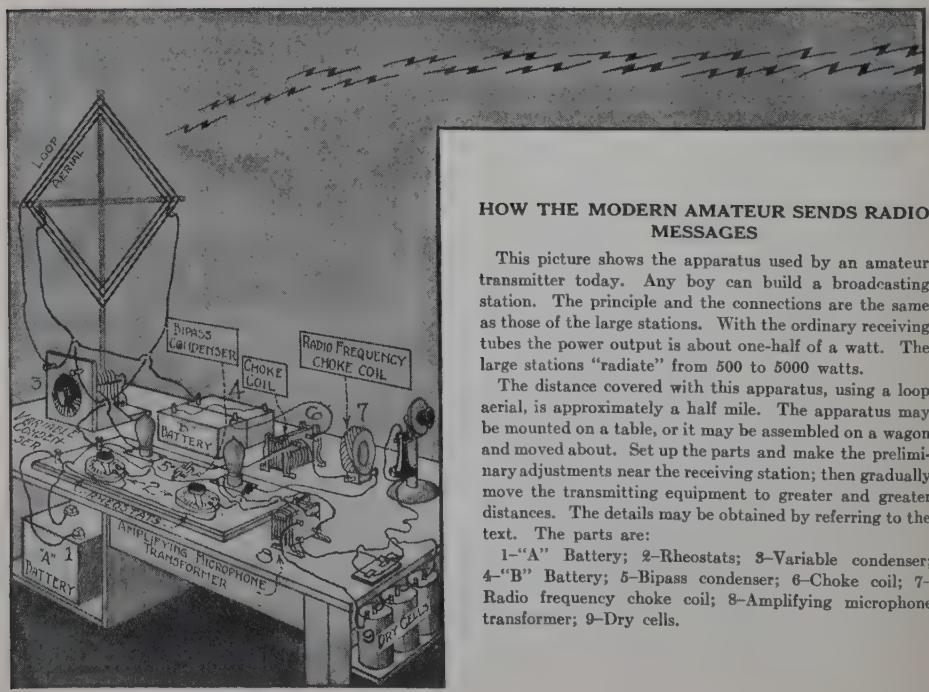
*A simple transmitter can be made of the ordinary receiving tubes. All the fundamental principles and adjustments of any transmitter can be shown with this transmitter. With it, speech can be transmitted a half mile with power input of about a half watt. Any broadcast receiver can be used as the receiver. For details of construction see *Experimental Radio*, 3rd edition, R. R. Ramsey, Ramsey Publishing Company, Bloomington, Indiana.



HOW AMATEURS FORMERLY SENT RADIO MESSAGES

This picture shows a boy using the most simple apparatus possible, used at the time when radiotelegraphy had just been invented. This apparatus is so crude and inefficient that the United States Government has forbidden its use. However, it illustrates the principle of radiotelegraphy.

When the key is pressed down the circuit of the battery is closed, so the current flows through the induction coil. The vibrator starts vibrating like the clapper on an electric doorbell. Every time the vibrator begins to vibrate the coil charges the antenna and causes a spark to pass between the balls of the spark gap. Each spark is perhaps twenty-five oscillations. This sends out twenty-five waves. If the key is held down while the vibrator makes twelve or fifteen vibrations, there are twelve or fifteen groups of waves sent out, and we call this a "dash." If the key is held down while the vibrator makes four or five vibrations, we have that many groups of waves, and we call this a "dot."

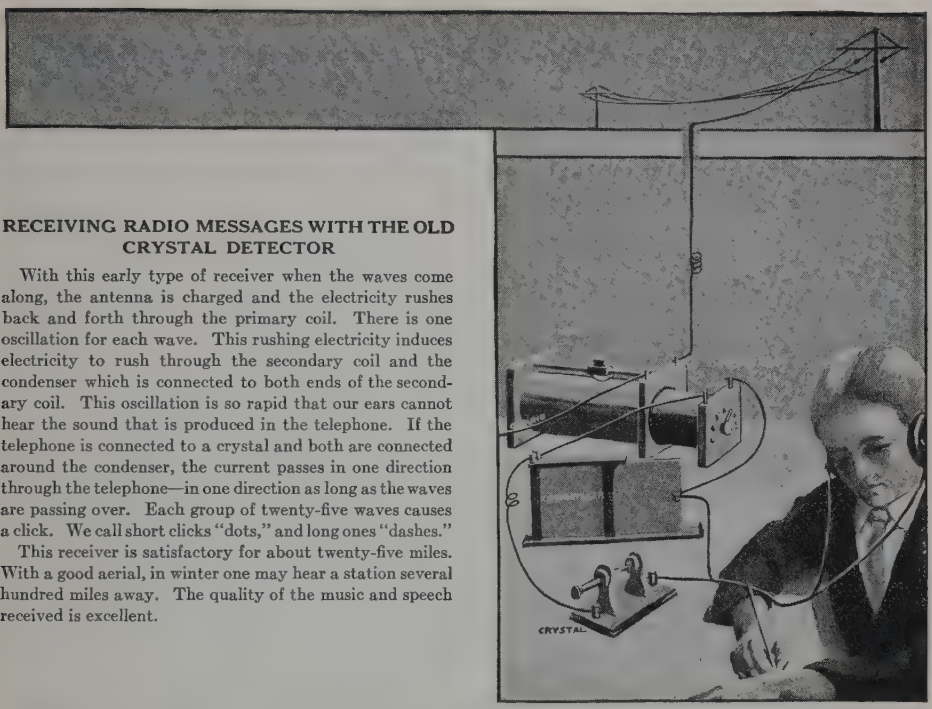


HOW THE MODERN AMATEUR SENDS RADIO MESSAGES

This picture shows the apparatus used by an amateur transmitter today. Any boy can build a broadcasting station. The principle and the connections are the same as those of the large stations. With the ordinary receiving tubes the power output is about one-half of a watt. The large stations "radiate" from 500 to 5000 watts.

The distance covered with this apparatus, using a loop aerial, is approximately a half mile. The apparatus may be mounted on a table, or it may be assembled on a wagon and moved about. Set up the parts and make the preliminary adjustments near the receiving station; then gradually move the transmitting equipment to greater and greater distances. The details may be obtained by referring to the text. The parts are:

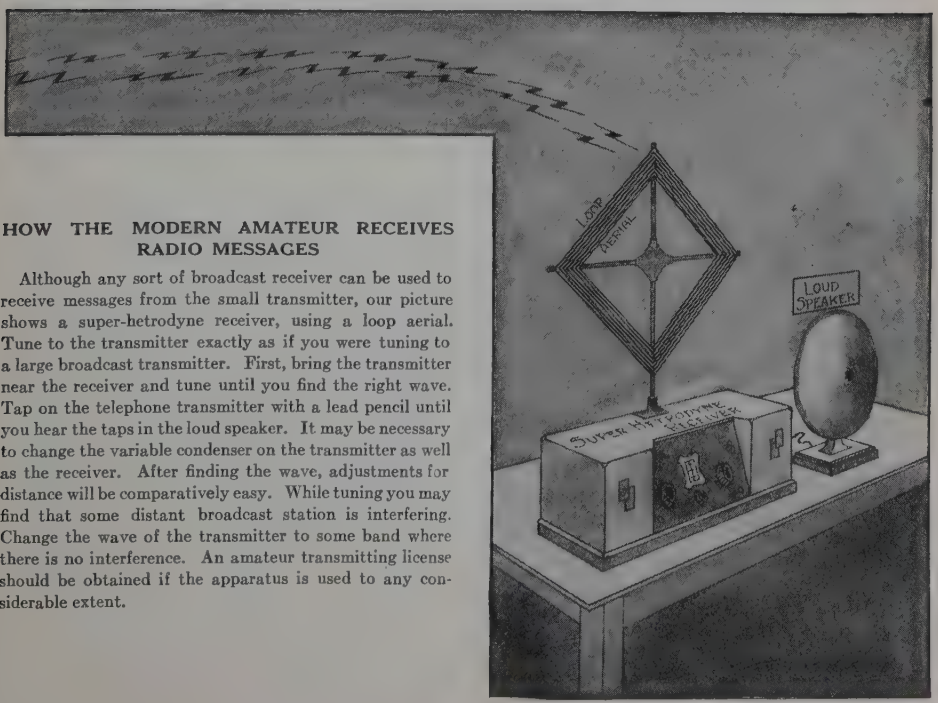
1–"A" Battery; 2–Rheostats; 3–Variable condenser; 4–"B" Battery; 5–Bipass condenser; 6–Choke coil; 7–Radio frequency choke coil; 8–Amplifying microphone transformer; 9–Dry cells.



RECEIVING RADIO MESSAGES WITH THE OLD CRYSTAL DETECTOR

With this early type of receiver when the waves come along, the antenna is charged and the electricity rushes back and forth through the primary coil. There is one oscillation for each wave. This rushing electricity induces electricity to rush through the secondary coil and the condenser which is connected to both ends of the secondary coil. This oscillation is so rapid that our ears cannot hear the sound that is produced in the telephone. If the telephone is connected to a crystal and both are connected around the condenser, the current passes in one direction through the telephone—in one direction as long as the waves are passing over. Each group of twenty-five waves causes a click. We call short clicks "dots," and long ones "dashes."

This receiver is satisfactory for about twenty-five miles. With a good aerial, in winter one may hear a station several hundred miles away. The quality of the music and speech received is excellent.



HOW THE MODERN AMATEUR RECEIVES RADIO MESSAGES

Although any sort of broadcast receiver can be used to receive messages from the small transmitter, our picture shows a super-hetrodyne receiver, using a loop aerial. Tune to the transmitter exactly as if you were tuning to a large broadcast transmitter. First, bring the transmitter near the receiver and tune until you find the right wave. Tap on the telephone transmitter with a lead pencil until you hear the taps in the loud speaker. It may be necessary to change the variable condenser on the transmitter as well as the receiver. After finding the wave, adjustments for distance will be comparatively easy. While tuning you may find that some distant broadcast station is interfering. Change the wave of the transmitter to some band where there is no interference. An amateur transmitting license should be obtained if the apparatus is used to any considerable extent.

miles. The advancement of the radiophone is such that the principle of the carrier wave has been applied to wire lines enabling a large number of subscribers to use the same line as party line all at the same time and one not to interfere with the others.

The early days of broadcasting

Superpower companies use their transmission lines as telephone lines. The lines may be transmitting thousands of horsepower of energy at one or two hundred thousand volts at the same time.

During the winter of 1920-21 The Westinghouse Electric and Manufacturing Company of Pittsburgh, Pa., erected a radio transmitting station and began sending out regular musical programs. This was received by the public with so much favor that the next winter they opened two more broadcasting stations. These, together with a large number of other transmitting stations, are sending music, readings, stories and lectures every night. At first the amateur radio operators were the only persons who listened in, using their radiotelegraphic receivers. These amateurs invited their friends to listen. Their friends became interested and asked how they might rig up a set to listen in. After procuring sets they found that they could hear a concert given at a point hundreds of miles away. During the winter of 1921-22, radiotelephony swept the country.

It is possible now to hear music from a station a thousand or two thousand miles away, and even from other continents. This is due to one thing—the triode vacuum tube.*

Chain broadcasting

Not only are there a large number of broadcasting stations, but, at times, a number of stations broadcast the same program at the same time. This is known as a chain or system. Thus we speak of the National Broadcasting Chain and the Columbia Broadcasting System or more briefly NBC and CBS. Usually chain broadcasting is accomplished by connecting the various stations with commercial telephone wires; at other times by radio transmission. Short wave lengths are used in international broadcasts. The program is transmitted by wire to the station nearest the coast and from there it is carried by short radio waves to the nearest coastal station across the ocean. From this station the program goes by wire to the "key" station of the chain and is rebroadcast.

It is possible to connect any number of stations in a chain. There is no reason why every citizen of the United States cannot hear the President make an address. The President may read his address while seated at his desk in the White House.

Broadcasting by remote control

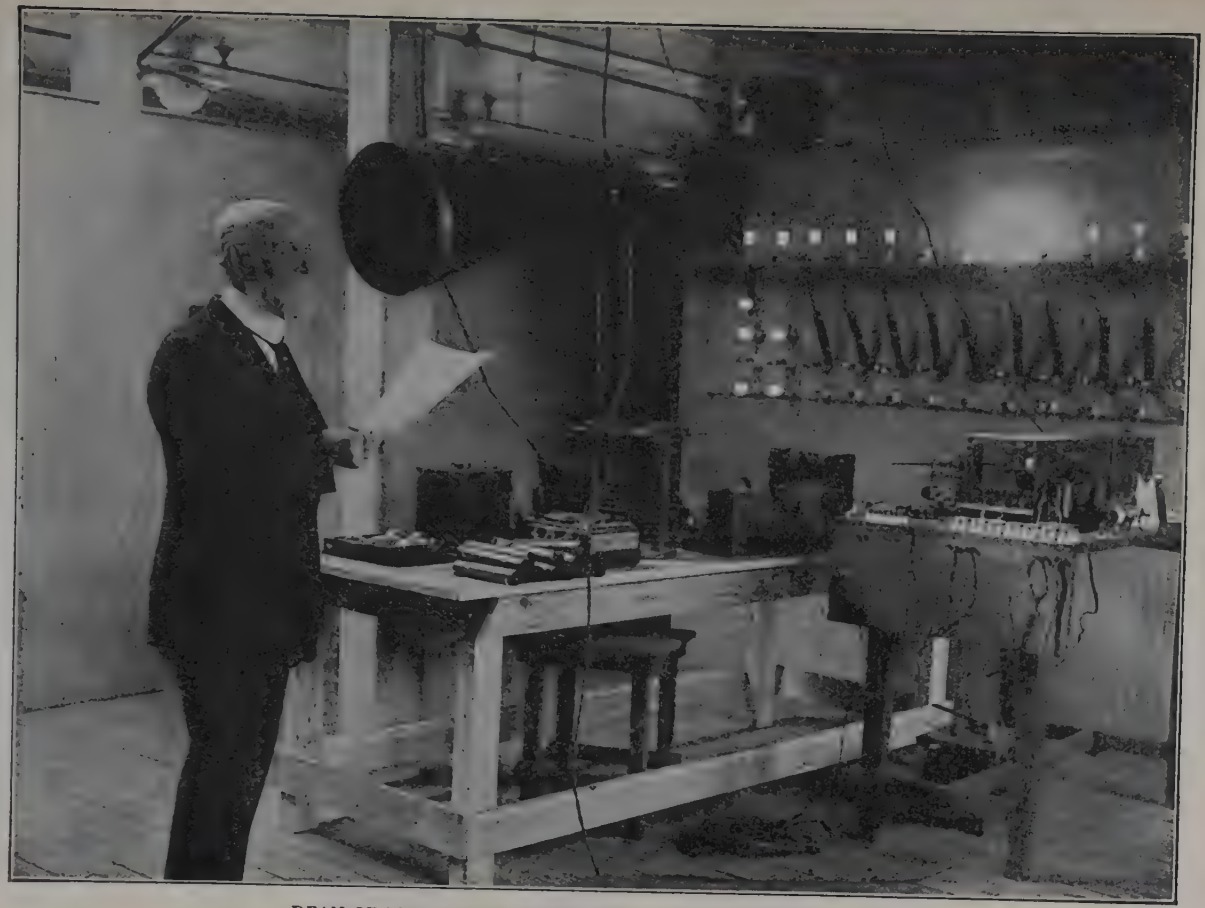
Programs by "remote control" are handled similarly. Most stations use the local telephone lines. Some have a special transmitter mounted on a truck. This is taken to the church, theater or auditorium and the program is transmitted on short waves, picked up by the sending station and rebroadcast.

The receiving sets are the same as the receiving sets used in radiotelegraphy. The broadcasting band is from 200 to 545 meters.

Radio receiving sets

If you live not more than ten miles from a good transmitting station, you can use a crystal set. A crystal set is very simple to operate and may be

*This is the correct name, although they are called "tubes" for short. In England they are called "valves." Sometimes they are called "bottles."



DEAN OF TUFTS COLLEGE DELIVERS FIRST LECTURE BY RADIO

Professor Charles Ernest Fay, dean of Tufts College of Boston, Mass., delivering the first radio lecture. Dr. Fay officially opened Tufts College wireless educational feature, and is shown here reading his address into the large horn-shaped microphone in the Amrad laboratories at Medford Hillside.

constructed very cheaply. Occasionally a crystal set will work a distance of fifty or a hundred miles or more. This is when the aerial is located in an unusually good location and all adjustments are perfect.

For great distances one will need a good receiver. This may be an expensive radio frequency amplifier or hetrodyne receiver or it may be a very simple receiver of the regenerative type. If you use a regenerative receiver, you should be very careful that the tube does not oscillate and disturb the neighbors who may be trying to receive at the same time. A regenerative receiver, when allowed to oscillate, is a tube transmitter, and sends out a carrier wave which is very annoying to anybody trying to receive from a station which is very near the wave of the regenerative receiver.

The elaborate receivers are too complicated to be described here. Blue prints, diagrams and directions for building them can be purchased at radio stores or can be found in radio magazines.

A simple regenerative set can be made by any boy who will follow the directions given below. Although directions are given for making tube sockets, condensers and rheostats, it may be as well to buy these. The coils can be wound and the apparatus assembled by anybody.

An inexpensive radio receiver

You will need an A battery which is a six-volt storage or dry cell battery, according to the kind of tube used. The storage battery tube has a greater amplification constant, but the dry cell tubes are somewhat more convenient. Besides the A battery, you will need a 22½-volt or a 45-volt B battery, a good pair of head phones (do not make the mistake of getting cheap phones), two variable condensers, a socket for the tube, a tube, a rheostat, two fixed condensers, and perhaps a grid leak and a good aerial.

The tube, phones and B battery are all one needs to buy. For a storage battery, use the automobile battery. This can be done by running two wires and connecting to the battery in the machine. The garage will make a good radio station. The rheostat can be made of broom wire wound on a porcelain tube or on a bottle. A socket can be made by boring a hole whose diameter is the same as that of the base of the tube in a 1½ inch block and arranging four clips made of spring brass wire to touch the four terminals.

A good grid condenser can be made of two sheets of tinfoil placed one on each side of a 4x5 photographic plate. Wire terminals are connected to each sheet of foil. For protection, place two extra photographic plates on the sides. For a by-pass condenser around the phone, use four or five sheets of tinfoil with photographic plates placed between each sheet. Connect 1st, 3rd, and successive odd numbered sheets, to one wire and 2nd, 4th, and successive even-numbered ones, to a second wire for a terminal. The sheets of tinfoil should be smaller than the glass plates.

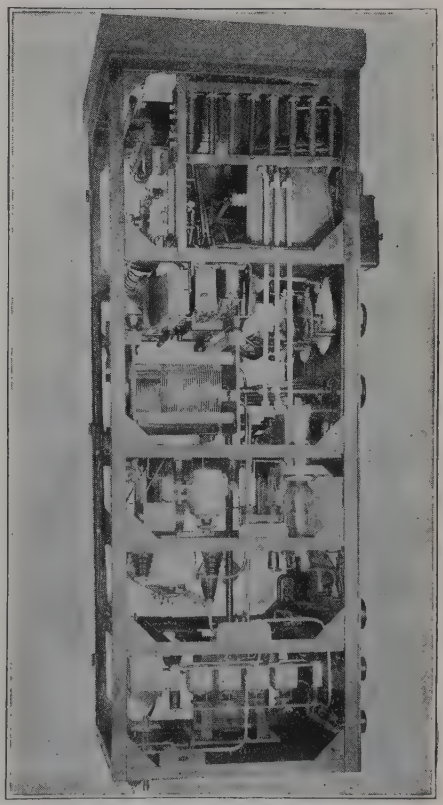
If a good variable condenser can not be obtained, make one. Take two photographic plates and shellac a sheet of tinfoil, such as the wrapper of certain candies or chewing gums, to each plate. One end or edge of the tinfoil must reach beyond the edge of the glass plate for connection. Get some mica and split it as thin as possible and place over one of the sheets of tinfoil. Place the second sheet over the mica. The closer the two sheets of tinfoil can be brought together without making electrical contact, the

greater the capacity of the condenser. The glass plates can be fastened to two small boards. These boards can be hinged at one edge so as to open like a book and the capacity can be changed by opening or closing the condenser. When open the capacity is small, and large when closed. A small bolt with a thumb nut can be placed so as to close the condenser gradually and a small coil spring can be placed to open the condenser as the nut is reversed. Variable condensers may be purchased for $1.75 or less.

Regenerative receiving coil

Procure 100 feet of No. 24 cotton-covered copper wire. Wind this wire on a rolled oats box or on any paper tube whose diameter is about four inches. Make three coils of twenty-five turns of wire in each coil. Wind the coils one layer deep. Leave a space of about one-half inch between each coil. Each coil will have two terminals—six terminals in all. Number the terminals 1, 2, 3, 4, 5, 6, numbering from left to right. Connect No. 1 to the ground, No. 2 to the aerial. Connect No. 3 to the grid terminal of the tube, No. 4 to the negative filament of the tube. Connect one of the variable condensers to terminals No. 3 and 4 also. Connect No. 5 to the negative filament of the tube, No. 6 to one terminal of the phone, the other terminal of the phone to the negative terminal of the B battery and the positive terminal of the B battery to the plate terminal of the tube. The by-pass condenser should be connected around the phone terminals and the grid condenser placed in series in the grid circuit. The second variable condenser is placed in series or in parallel with the coil connected to the aerial. This makes a good regenerative circuit. All high-power phone stations within a radius of 1,000 miles can be heard with this outfit on good nights.

This coil may be made into a variable coupler by cutting the coils apart and fastening the coils to wooden blocks. Fasten the middle coil rigidly to a wooden support and by means of hinges fasten the other two on each side of the first so that they will swing like the leaves of a book from a position parallel to the middle coil to a position at right angles to the middle coil. Mount so that when the coils are closed they occupy the same relative position that they did before they were cut apart. Six binding posts, one for each terminal, will add to the con-



TRANSMITTER MECHANISM

A transmitter used in broadcasting is shown here with the screens removed.

venience of this coil. The approximate cost will be:

Receiving tube	$0.50	to	$1.00
Phones	1.00	"	3.00
A battery	1.50	"	5.00
B battery	1.00	"	3.00
Rheostat	.25	"	1.00
Socket	.25	"	1.00
Wire	.25	"	1.00
Condensers	.25	"	2.00

MARY GARDEN BROADCASTING

The famous opera star finds that singing to silent millions over the radio is a thrilling experience. She is shown at the microphone of WJZ.

Receiver using a crystal detector

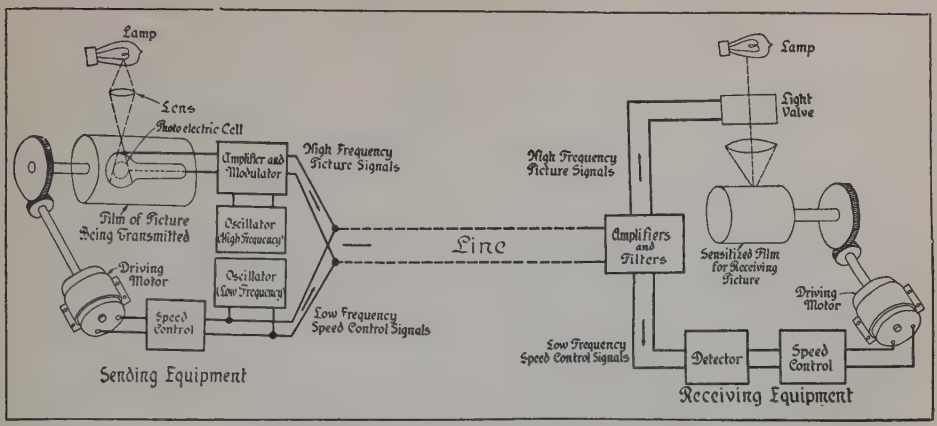
The coils may be constructed as in the regenerative receiver, except that only two coils of twenty-five turns each are needed.

Numbering the terminals from left to right 1, 2, 3, 4, connect No. 1 to the ground, No. 2 to one terminal of a variable condenser, the other terminal of the condenser to the aerial, Nos. 3 and 4 to the terminals of a second variable condenser. To the terminals of this second condenser also connect one terminal of the crystal detector and one terminal of the telephone. The extra terminal of the telephone is connected to the extra terminal of the crystal detector.

The crystal detector consists of a crystal of galena, a lead ore, mounted in a holder or imbedded in solder; a "cat whisker" copper wire makes light contact with surface of the crystal. Certain spots on the crystal will be found to be more sensitive than others. These spots must be found by trial.

Receiving aerial

The best all around receiving aerial is a long copper wire, No. 20 or larger, 150 to 200 feet long, placed about thirty-five feet high. Porcelain cleats, such as are used for fastening wire in houses, make good insulators for a receiving aerial. Stretch this wire between two supports. House, barn, poles or trees will do. If possible select a high open space. A tree under or near an aerial absorbs a great amount of energy. Get a single pole, double throw knife switch, and fasten it to a wooden post two feet from the house. The switch may be fastened to the house, but there may be some objections from the insurance men. Connect a wire which is connected to an iron pipe driven deep into the ground to the lower point of the switch. Connect the aerial to the middle point and a wire which leads in to the receiver to the top point. When the aerial is not in use the switch should be turned so as to connect the aerial to the ground. This is for protection from lightning. If a good lightning arrester is installed, the switch may be omitted.



SENDING AND RECEIVING PICTURES BY WIRE

The schematic arrangement of the original apparatus for transmitting and receiving pictures over telephone lines. Developed by American Telephone and Telegraph Company and Western Electric Company, Inc.

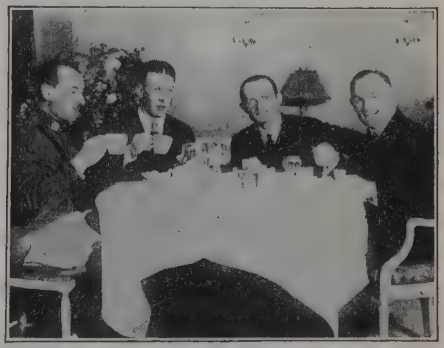
PICTURES BY WIRE OR WIRELESS

UNTIL comparatively recently news stories were printed in one issue of a newspaper and later, often days later, the news photograph illustrating the story arrived by mail and appeared in the paper. Thanks to a series of notable inventions, it is now possible to receive pictures over the wires of the telephone system or by means of the radio.

HOW PICTURES ARE SENT BY WIRE

The number of different devices which may be designed to transmit pictures electrically over great distances is almost infinite. Any communication wire supplies the fundamental requirement for the electric transmission of pictures. It furnishes a channel over which information can be passed very quickly, and, with the proper understanding between the person sending and the person receiving, this information can readily be such as to enable the latter to reconstruct, with any desired degree of accuracy, whatever picture the sender may have before him.

For example, these two persons may agree to divide pictures up into a regular checkerboard arrangement of little squares. They may call the square in the upper left hand corner *No. 1*, the next one to its right *No. 2*, and so on across and down through the checker-

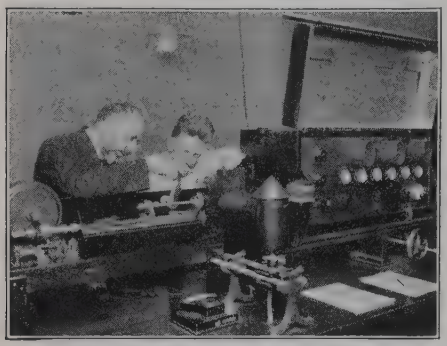


BREAKFAST AT THE RITZ

German-Irish flyers of the *Bremen*, in New York, April 30, 1928. From left to right: Fitzmaurice, Schiller (American aviator who went to the relief of the *Bremen* crew on Greenly Island), Huenefeld and Koehl. (See Page 490.)
This is an example of the photographs that are received after having been transmitted from coast to coast over telephone wires.

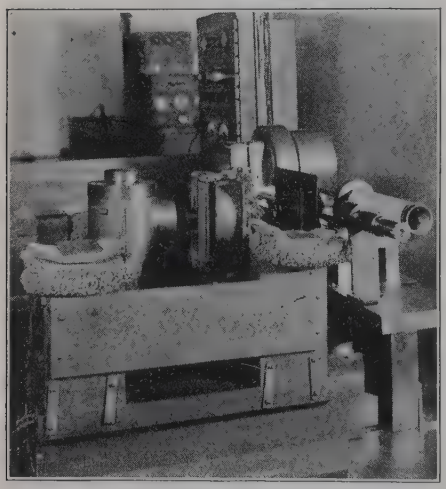
board arrangement until they reach the last square in the lower right hand corner whose number might, for example, be *No. 10,000*. Then beginning with square *No. 1* the sender may transmit a message as follows: *No. 1*

white, No. 2 gray, No. 3 gray, No. 4 black, No. 5 white and so on through the whole series of 10,000 squares. The shades or colored tones which the sender will associate with each square will correspond with those in the pic-



TRANSMITTING APPARATUS

For sending pictures by wire. The synchronous motor is on the left. A film carrying a picture is being inserted. The amplifier, which receives impulses from the photo-electric cell, is in the box on the right. The cell is within the cylindrical form around which the film is wrapped.



RECEIVING APPARATUS

For receiving pictures by wire. The sensitive film rolled in cylindrical form is shown in the foreground to the right. The lamp house with the light valve is to the left. The synchronous motor for driving the film lies behind. In the background is the control panel on which the long distance telephone circuit terminates.

ture which he desires to transmit so that upon the receipt of such a message the person at the far end of the telegraph line will immediately fill in his blank checkerboard with the substitute shades or colors. He will thereby obtain a copy of the original picture, the accuracy of which is limited only by the number of little squares into which it had been agreed beforehand the picture was to be divided.

Now such a simple descriptive method for transmitting pictures would obviously be so slow as to be unsuited for practical applications. A practical system must reduce the time required and expense involved to the very minimum. This means that wherever possible the breaking up of the original picture into little units or elements and the reassembling of these at the distant end be made automatic. This was accomplished to a high degree of perfection by a system of picture transmission developed a few years ago by the telephone engineers of the Bell System and which operated so rapidly that a complete picture such as the picture on Page 409 of the *Bremen* flyers could be transmitted thousands of miles and even to a number of widely separated points simultaneously in a few minutes time. Line drawings, handwriting and painting were also transmitted and facsimiles sent by wire for the press and for business concerns.

The diagram on Page 409 illustrates the operation of the original system. The picture to be transmitted was first copied photographically on a transparent film. This film was inserted in the transmitter simply by rolling it up into a cylindrical form. During operation a very small and intense beam of light shone through the film onto a photo-electric cell within. The film was rotated at a uniform speed, and by means of a screw mechanism was caused to advance parallel to the axis of the cylinder. The motion of the light relative to the cylinder was therefore the same as that of a phonograph needle relative to a cylindrical record. In this way, each minute

portion of the picture in turn affected the intensity of the light reaching the photo-electric cell. This variation in the amount of light striking the sensitive surface of the cell gave rise to a current which, through the agency of a vacuum tube amplifier and modulator, controlled the current flowing through the telephone line.

At the receiving end, an unexposed photographic film was rotated under a beam of light in a manner similar to that at the transmitting end. The two films were caused to rotate at exactly the same speed and the impulses starting from the photo-electric cell at the sending end controlled by means of a new device known as a light valve, the amount of light reaching the film at the receiving end.

The present method is to work direct from a positive print, the light being reflected from the print to a photo-electric cell. This modification has speeded up the operation.

Close examination of pictures which have been transmitted electrically show that they consist of a fine structure of parallel strips, equal in width but varying in photographic density. These lines, of course, result from the fact that the record is traced on a succession of narrow strips one at a time, as the receiving film rotates and while rotating is advanced by a screw.

It is obvious that immediately good black and white photographs can be sent, any other kind of picture which can be recorded as a black and white picture or as a series of such pictures can also be sent. Among such, for instance, are stereoscopic photographs. Marked success has been attained in the transmission of colored photographs.

On April 14, 1928, the first motion pictures by wire were transmitted from Chicago to New York. The film star, Miss Vilma Banky, was photographed at 10:30 A.M. From the negatives, positives were made and transmitted to New York. The received negatives were cut into strips, punched, pieced together and a positive film printed. It was ready for showing within five hours of the time the picture was taken in Chicago. The film was exhibited in New York the same evening.

MOTION PICTURES BY WIRE

The first moving pictures ever sent by wire—a close-up of Miss Vilma Banky, photographed in Chicago and transmitted by wire to New York. Ten feet of this close-up were cut into six-inch strips having eight frames each. These strips were numbered consecutively and placed between glass plates three at a time. As explained in the text, positives were made and sent to New York in the regular way.

PICTURES BY RADIO — THE PICTORADIOGRAM

Mr. Owen D. Young was addressing a gathering of radio experts in New York City. He painted a word picture of the time when photographs would be sent across the Atlantic; when the newspaper account of an event of world interest flashed across the seas would be accompanied by photographs

of this event. Mr. Young said, "Zip, and the front page of a London newspaper is in New York." The idea set the radio men to thinking and the result is the pictoradiogram

Although much work remains to be done in order to develop this method of sending pictures by radio, remarkable results have already been obtained. The experimental work has been carried on with the established radio-transmitting stations now engaged in sending radiograms daily. Thus the new device does not require any special radio circuits for its operation.

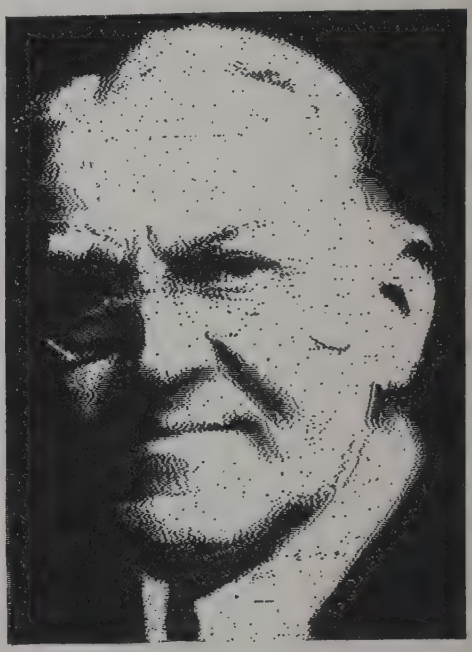
Courtesy Radio Corporation of America

INVENTOR OF THE PICTORADIOGRAPH

Mr. R. H. Ranger of New York, inventor, with his apparatus for sending pictoradiograms. In his left hand he holds the film of a picture to be sent by radio.

In a way somewhat similar to that described for the transmission of pictures by telegraph, the picture is started on wires.

The wire method of sending the amplitude-modulated electrical signals is not practical for long distance radio transmission on account of fading, which distorts at the receiving end. This difficulty has been solved by converting the amplitude-modulated current supplied by the photo-electric cell of the scanner into a series of positive impulses of varying duration. Thus, instead of sending a continuous signal whose *strength* varies with the black and white areas of the subject matter, the radio method sends a series of dashes of various *length*. These dashes, when reassembled at the receiver, form a picture not unlike a halftone engraving, which is made up of solid black dots of varying diameters.

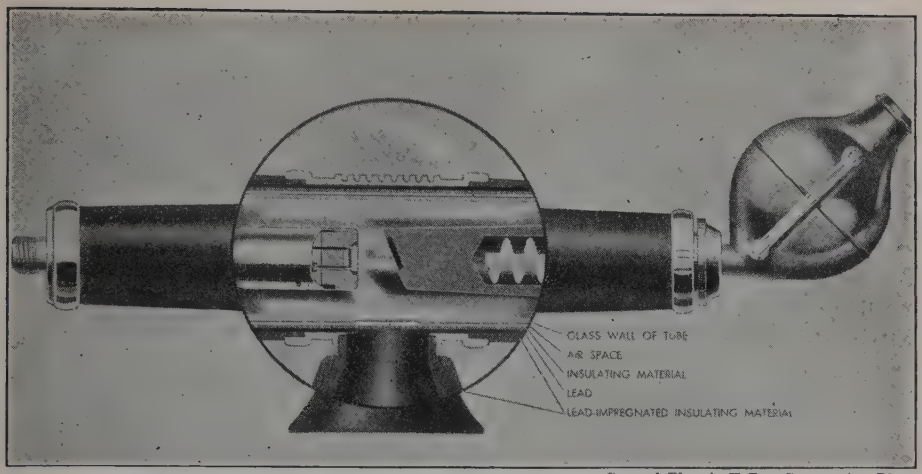


Courtesy Radio Corporation of America

SENT BY RADIO

This picture was sent by radio from Honolulu to San Francisco and thence, also by radio, to New York. The time required for transmission from Honolulu to New York was just twenty minutes.

In a word, the radio system of transmission goes through two steps, as compared to one for the wire method, for it converts light and shadow of the subject into a continuous signal, modulated as to amplitude, and then converts that into a series of dashes, modulated as to time.



General Electric X-Ray Corporation Photo

MODERN X-RAY TUBE

Showing the modern (Coolidge type) x-ray, a development from the form shown in diagram on the next page.

X-RAYS

IN December of 1895, Professor Roentgen of Wurzburg University, in Germany, announced to the world one of the greatest discoveries of the century—a discovery whose far-reaching effects must rank as one of the greatest events of all times. The laboratory had given up another secret; and the mysterious rays, which for lack of a better name were called "x-rays," took their place among the tools of science that work for man.

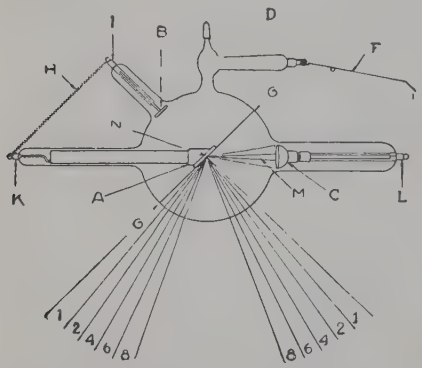
Roentgen's discovery was the result of a long series of experiments with vacuum tubes, tubes from which practically all air is withdrawn. As far back as the eighteenth century the Abbé Nollet arranged an electrical apparatus in such a manner as to send a spark through a glass globe which he gradually emptied of air. The experimenters kept working, but it was not until 1859 that important results were obtained. In that year, Plücker was successful in getting a far higher vacuum than any before known, and produced with it a curious, greenish glow that lined the walls of the tube. This was said to be due to the action of cathode rays.

WILHELM KONRAD ROENTGEN
Discoverer of the Roentgen or X-Rays.

WHAT ARE THE CATHODE RAYS

The reader must learn the meaning of a few terms, perhaps new. The

cathode is nothing more nor less than the negative pole in the tube, as shown by our drawing. It is the point at which the electric current leaves the tube. The positive pole, or the point at which the current enters the tube, is called the anode. Plücker's work really formed the starting point of observations that led to the discovery of the x-ray itself.



OLD STYLE X-RAY TUBE

Outline of the old type x-ray tube—a vacuum tube containing two essential parts: the anode or positive pole A and the cathode or negative pole C. The lines M indicate converging streams of cathode rays, which strike upon the center of the anode giving rise to the production of x-rays, indicated by the letters 1 to 8 inclusive. The other letters point to accessories which have to do with the regulation of the tube.

The Work of the Late Sir William Crookes

In 1879 Professor Crookes, with a very high vacuum, obtained powerful rays, which he directed against a sort of windmill, or vane, placed within the tube, the vane revolving under the force of the rays. This and other experiments led Crookes to state the theory that the cathode ray was a stream of very small parts of matter charged with negative electricity.

What Roentgen Found in His Laboratory

A year later Professor Roentgen was working in his laboratory one day. On a screen beside his vacuum tube lay a small quantity of a chemical placed there quite by accident. The crystals were of barium platino-cyanide. Happening to glance down at the screen, the professor saw that the crystals were aglow. To find out whether this glow, or phosphorescence, could be due to the cathode rays, he covered both the tube and the screen, and lo! not only did the glowing continue, but dark shadows were cast on the screen by the hand and other objects placed between the tube and the screen. Thus was discovered, by accident, a new ray. Because nothing whatever was known of it, and because the symbol for unknown things was "x," the Professor called it the "x-ray." Later it has become known universally as the Roentgen ray. Great excitement throughout the scientific world greeted the discovery and many and ingenious were the explanations that arose to account for the new rays.

Some Mysteries of Matter

Sir J. J. Thomson at Cambridge found the cathode ray to be merely a stream, or beam, of electrons (minute particles of negative electricity) shooting out from the cathode at the tremendous speed of 60,000 miles a second. The fact that these rays can be bent at will, whereas the x-rays resist every attempt to change their courses, showed that they are different kinds of rays.

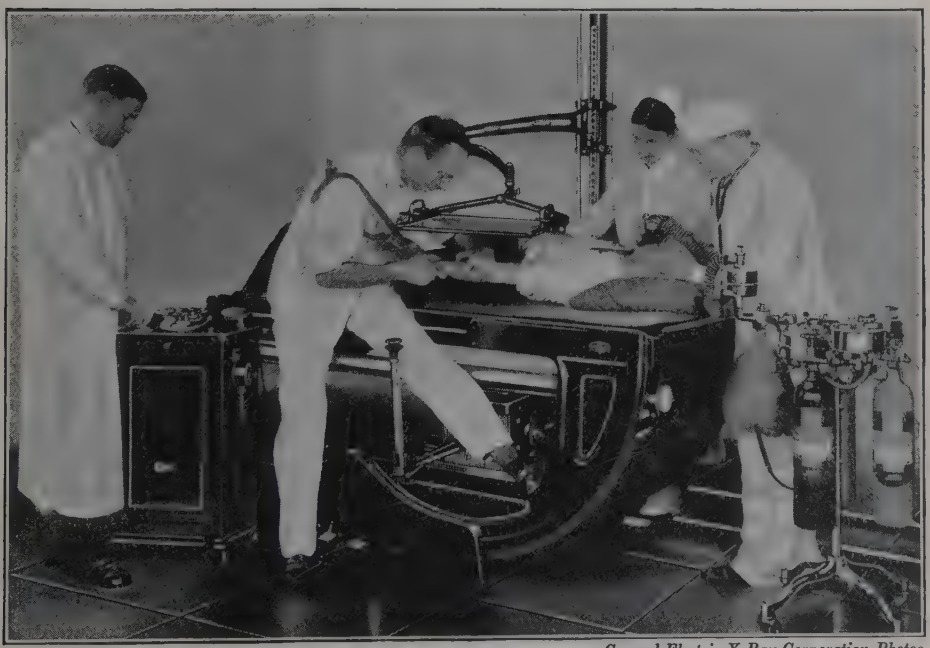
We now know that x-rays are vibrations of ether, something like light rays, but faster. They pass easily through many materials that ordinary light cannot enter, such as wood, paper and flesh. Denser subjects like lead, silver or gold stop most of the rays.

Caution Must Be Used in Working With These Powerful Rays

In x-ray work the operator must be careful. Although it is extremely rare that a patient suffers unfavorable effects, dreadful sores are sometimes formed upon the hands of the worker who is continually exposed to the rays. Even the constant study of their action

PORTABLE X-RAY APPARATUS

Making an x-ray study of a fractured knee. The equipment is easily brought to the patient's bedside.



General Electric X-Ray Corporation Photos

WORKING UNDER COMPLETE X-RAY CONTROL

Setting a fracture under x-ray (fluoroscopic) control. The surgeon sees the relation of the bone fragments as he adjusts them.

by means of a fluorescent screen hurts the eyeballs, causing them to become inflamed. The intense energy gives rise to what are called secondary radiations. It breaks bits off the atom against which it strikes continually; and when these atoms happen to be in the living flesh of the operator the result is sometimes serious.

In the past, several hundred brave men who worked in hospitals with great benefit to thousands of injured patients have lost their fingers, hands or arms through the strange, spreading sores produced by daily exposure to the power of the x-rays. These dangers are now nearly all done away with by modern protective devices.

It must not be thought that a patient nowadays is in any danger when the x-ray is used upon him by a skilled operator to find some broken bone, or some diseased organ, or some foreign body, such as a bullet or needle that has become imbedded in his flesh. The roentgenologist is fully protected against danger from the x-rays except (1) when employing the fluoroscopic screen in the study of the lungs, heart, or the digestive organs, and (2) especially when employing the x-rays as an aid in the removal of bullets and other foreign bodies or in the more accurate setting of fractures.

Treatment of disease by the x-ray

In addition to their use in diagnosis the x-rays may be used to great advantage in the treatment of many diseases. Practically any chronic disease of the skin and some acute skin affections, respond favorably. Cancer of the skin is especially amenable to x-ray therapy. Indeed, thanks to the modern refinements in the production of powerful x-ray apparatus utilizing high voltages, even up to 700,000 or 800,000 volts, and by the aid of complex but accurate devices for the measurement of x-ray dosage, it is now possible favorably to influence many types of deep-seated malignant disease, especially cancer of the female reproductive organs, the breast, the mouth, tongue, lips, larynx and pharynx, producing in some of these conditions a higher percentage of cure than previously obtained with surgical means. It is often necessary to produce temporary damage to the skin which in former days would have dismayed both patient and physician, but now it is possible to manage these reactions so that no harmful results persist, and it is often necessary to produce these skin reactions to affect the deep-seated malignant disease.

Some interesting details of work with x-rays

In these days of modern improvements in technique and apparatus, it is possible to make accurate measurements not only of the current used in diagnostic work but also in treatment. With lead-glass and lead-impregnated rubber it is now possible to protect the eyes, face, hands and body of the physician and his associates from damaging effects of the prolonged exposure they are required to make of themselves during x-ray examinations and treatment.

The physician's work has, moreover, been greatly lightened by the progress made in x-ray photography. In a general way, the x-ray is used for finding out what is the matter with the patient. This can be done in some cases much more accurately by means of photographs of the interior of the human body than by studying the actual image thrown on the fluoroscopic screen, for the radiographs can be closely examined in broad daylight and at leisure and compared with similar radiographs of the flesh, bones and organs of healthy people. For this reason x-ray photography has become,

General Electric X-Ray Corporation Photo

DENTAL X-RAY EXAMINATION

The x-ray is of great importance to the dentist. Small films are placed in the mouth. The negative often reveals hidden conditions as explained on page 420.

both for the surgeon and the physician, the most important by far of the medical uses of the new force and inventors are still busy in perfecting this branch of radiography.

At first there were obtainable only flat, dark shadows cast by the x-rays as they traveled through the human body. By using just a medium hard ray, which did not penetrate through the bones, the skeleton of the human frame could be shown in dark shadows amid the lighter tints of the flesh. The method was useful in discovering fractures of bones and foreign bodies of metals, such as bullets and splinters of shell in wounded soldiers, and needles and nails and other metallic objects due to accidents. It was early shadow-photographs of this sort that directed the general attention to the wonderful properties of the x-rays in the first years following their discovery.

But the trouble with a flat shadow-photograph was that it gave no indication of depth. It only showed outlines. In the case of broken bones this difficulty was overcome to some extent by taking several photographs—from the sides as well as from the back and front of the injured limb or other bony part—so the surgeon was fairly well contented with the series of flat shadow-pictures that the x-rays gave him.

It was some time, however, before the new unseen force, that can go through wood and steel, was of much use to the physician. In many cases he required a clear and perspective view of the flesh organs and of the softest parts of the tissues. And this is what he has now obtained. By using soft rays on certain parts of the body, and taking two separate photographs, and combining them for examination in a stereoscope, he can get a perspective view into the human body. Everything stands out in order in soft relief, so that various diseases of the lungs and heart and other organs can be traced.

By having the patient swallow a meal mixed with some opaque substance, such as barium sulphate, it is possible to visualize and record for study the entire digestive tube, and by the injection of opaque oils, properly sterilized, one may render visible the pelvic organs, the urinary tract, the gallbladder, the branches of the trachea and bronchial tubes, as well as the sinuses of the face, and with the aid of minor surgical measures to study the brain and spinal cord. All these rather complicated examinations become simple and highly valuable as an aid to the elucidation of various disease problems when used by a physician qualified to specialize in this branch of diagnostic medicine.

Great hopes for the future

Much yet remains to be done before the various forms of x-ray treatment and examination are perfected. Diseases of the brain are especially hard to trace by means of the x-ray, for the shadows of the bones of the head greatly dim the details of the soft structure. Moreover, as the rays pass through the skull, they produce cathode rays that still further blur the shadowy image of the brain. Yet a tumor mass in the brain has been revealed by the wonderful ray; and recently, by the injection of oxygen into the serum-filled cavities in the skull, brain tumors have been more easily and accurately discovered. Still more recently, by the injection of lipiodol, an iodized oil, into the spinal canal or into the windpipe, a whole new range of diagnoses has been made possible in diagnosing spine and lung diseases. The kidneys and the gall bladder are now also seen and more accurately studied by the use of new drugs which can be introduced

A SERIES OF X-RAY PICTURES OR ROENTGENOGRAMS

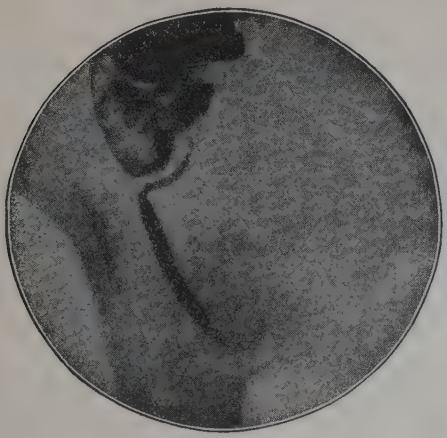


Figure C. The human vermiform appendix as it appears when filled with bismuth

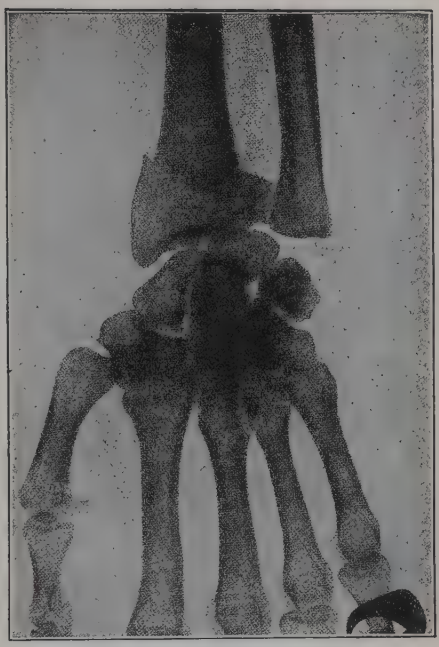


Figure E. The bones of the arm

Figure D. The foot enclosed in the shoe

Figure F. Skeleton of a squirrel

Figure G. Skeleton of a frog

into them. So we may expect the work of the modern operator to be at last developed to a point at which all the parts of the bodies of suffering mankind will be made clearly visible.

Dentists place great importance on the information furnished by x-ray examination of the teeth, utilizing small films placed inside the mouth to show the condition of the roots, the completeness of filling of root canals, the relation of unerupted teeth, hidden pockets of caries underneath inlays, and for many other purposes. In industrial circles, high-voltage x-ray apparatus is extensively used for the detection of flaws in metal tubing, weldings, castings, grinding wheels, air-plane parts and other products.

Cathode rays

In 1926, Dr. W. D. Coolidge, assistant director of the great research laboratory of the General Electric Company, announced the invention of a new and very powerful cathode ray tube. Cathode rays, consisting of streams of high speed electrons, discovered by Crookes in 1875, have been studied by various scientists.

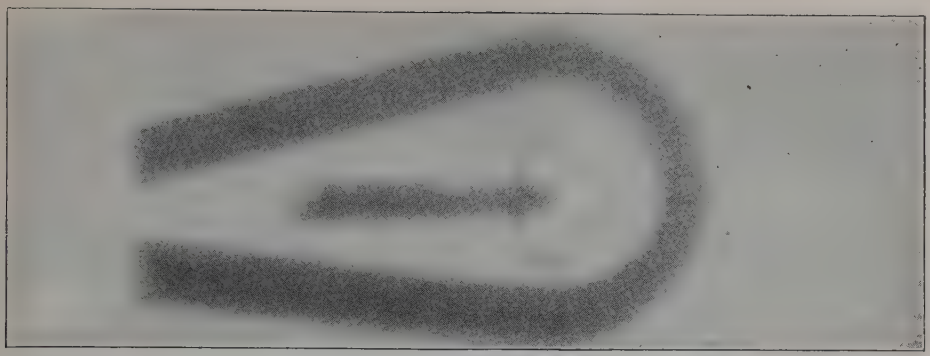
Dr. Coolidge has now developed a tube which uses a current of a few milliamperes and a voltage up to 350,000. The operation of the tube is similar to that of the hot electrode x-ray tube developed by Coolidge in 1913. The electrons escape through a metal window, causing the air to assume a purplish color, extending in front of and some distance in back of the window. This glowing, more or less spherical mass, small in diameter at low voltage, may be as much as two feet in diameter at high voltage. The light property is due to the ionization of the air by high speed electrons. Matter of any kind in the path of the rays becomes heated by the bombardment of the rays and at the same time causes a slight production of x-rays.

Contrary to x-rays, which do not kill bacteria, the 200,000 volt cathode rays are found to be deadly to bacteria. One milliampere of current for a fraction of a second causes immediate paralysis and subsequent death of fruit flies. With a very small dose, the hair of a rabbit's ear falls out, later to be replaced by snow-white hair. With a large dose, a hole was made in the rabbit's ear.

Dr. Coolidge made the statement that one of these cathode ray tubes will release as many electrons per second as a million grams of radium bromide. The cash value of this amount of radium bromide at the present market price would be somewhat like $60,000,000,000.

Cosmic rays

In November, 1925, Robert A. Millikan, Director of the Norman Bridge Laboratory of Physics, California Institute, and a recipient of the Nobel Physics Prize for his work on the electron, published the proof of the existence of a new kind of rays, called "cosmic rays," already studied by McLennan and Rutherford (1903), Gockel (1910), Hess and Kolhörster (1911-1914). Millikan and his associates found an extraordinarily hard radiation coming into our atmosphere from outer space; and since at all altitudes up to ten miles there was found no measurable variation in the intensity of these rays at any time between midday and midnight, it was concluded that these rays shoot through space equally in all directions. The hardest observed rays were found to have a wave length of .0004 Ångstrom units, corresponding to a frequency at least fifty times that of the hardest gamma ray (radium), a thousand times that of the average x-ray, and about ten million times that of ordinary light.



RADIUM SHADOWPRINT

Made by the author for *The New Human Interest Library*, using a twenty days' exposure on an x-ray negative. The magnet and key were placed directly upon the cardboard holder containing the negative and covered by a cardboard box containing a half-inch layer of high-grade carnotite ore.

RADIUM

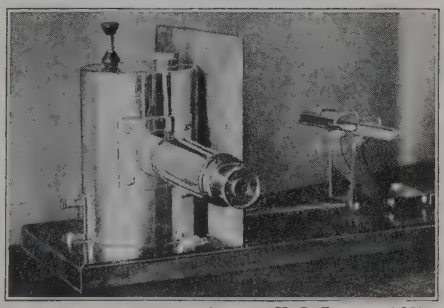
IT takes a ton of carnotite, a radium bearing ore, to yield an amount of radium equal in weight to an ordinary pinhead. This amount is worth about $10,000, and yet, on this basis, ten cents' worth of radium applied to the hands and numbers on the face of your watch enables you to read the time in absolute darkness.

THE FOUR CHIEF EFFECTS OF RADIUM

Radium is but one of at least thirty elements that show radioactivity. By radioactivity is meant the sending out of the wonderful rays, as explained later. Of the elements that have enough activity to be useful, radium is the most abundant. Like electricity, radioactivity was discovered and is largely known by its effects, of which there are four that are important.

First, there is the action on a photographic plate, which led to the discovery of radioactivity. It is shown in this way. Take an unexposed negative wrapped in heavy light-proof paper. Place a key upon this and a piece of carnotite ore on top of all, and leave it for a few days. Then, when the plate is developed, a picture of the key will be found on the photographic plate.

Next, and of greatest commercial importance, is the effect of radioactive bodies upon materials that give out light. This effect was mentioned in telling of the watch dial. A minute quantity of radium mixed with zinc sulphide and applied as a paint makes the figures and hands stand out in the darkness.



Courtesy U. S. Bureau of Mines

MEASURING RADIUM

Radioactive material is placed in the holder at the right. Minute quantities of radium are thus detected by this instrument.

The third effect can be shown as follows. If a silk tassel is rubbed with a rubber rod, it becomes electrified; and each thread, having an electric charge, repels its neighbors, with the result that the tassel spreads out in all directions, fan-wise. Now, if even a minute amount of radium is brought near the

tassel, the electric charge instantly goes, and the tassel hangs limp as before. An instrument based on this action is called the electroscope. It has a leaf of aluminum foil, one end of which is fastened to an insulated brass rod, the thin aluminum leaf behaving exactly like the tassel described above. When electrified, the leaf stands out from the rod. When radioactive material is brought near, the leaf drops. This instrument is used to detect even very small amounts of radium in ore. A tiny trace of radium can be detected by the use of an electroscope.

A fourth effect produced by all radioactive bodies is heat. Radium contains a tremendous store of energy. Although it gradually breaks up, only half of a given quantity will disappear in 1700 years. The amount of heat given off is a million times that produced by burning an equal weight of coal. This heat is liberated so slowly that the effect on its temperature is very slight.

Elements, atoms and electrons

Here we will need to know the meaning of the words "element" and "atom." Any substance which cannot be divided by chemical means into two or more other substances is called an element. Chemists have found that there are about ninety. Some of the commoner elements are iron, copper, sulphur, carbon and oxygen.

Every element is made of exceedingly small particles called atoms. Every atom is similar to every other atom of that element, and different in size, weight and other respects from those of all other elements. The weights of the atoms of the different elements have been very exactly worked out and are called the atomic weights. These weights are too small to be expressed easily as ounces or grams, and are usually given in terms of the lightest known atom, hydrogen. Thus oxygen, which has atoms sixteen times as heavy as the hydrogen atom, has an atomic weight of sixteen.

Electricity is also made of tiny individual particles. These are called electrons. It is the flow of these electrons along a wire that is known as an electric current. Before radium was discovered it was thought that atoms were the smallest particles of matter. But we now know that all atoms contain one or more electrons. All chemical and physical properties of an element are determined by the number and arrangement of the electrons in its atoms. All electrons, no matter where they come from, are exactly the same

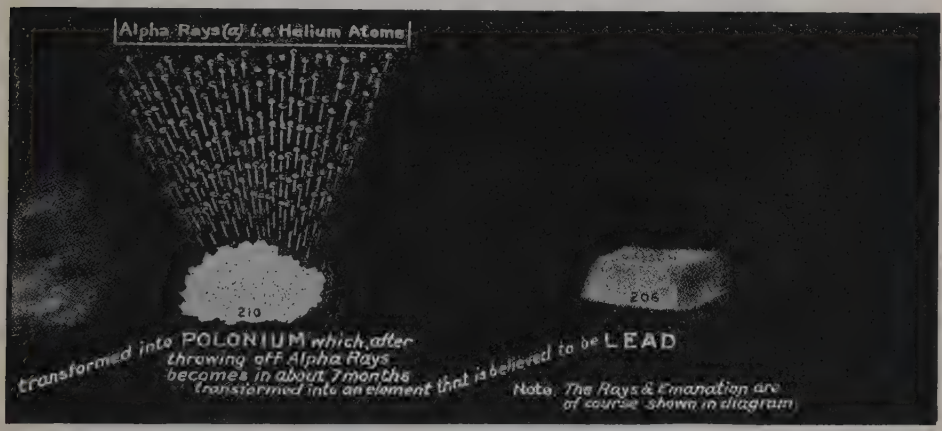
The three kinds of rays that produce radioactive effects

We now know that all the remarkable effects produced by radioactivity are caused by very small particles, or rays, which are hurled away from the atom, with a speed something like that of light. There are three kinds of rays, known as alpha, beta and gamma, the first three letters of the Greek alphabet.

The alpha rays have the most energy but the least penetrating power. They will travel not more than three inches in air, and even a thin piece of paper stops them completely. They are actual bits of matter, traveling about 12,000 miles per second, one-fifteenth as fast as light, and hundreds of times faster than any other material thing has ever been known to move. Experiments have shown that the number of alpha rays produced by a pinhead weight of radium is about 340,000,000 every second. The alpha ray carries two units of positive electricity and when it loses this electric charge it becomes an atom of helium, that rare gas with which we are familiar as a non-inflammable substitute for hydro-

Alpha Rays (α) i.e. Helium Atoms
Beta Rays (β) i.e. Negative Electrons deflected by Magnet
Gamma Rays (γ) i.e. Ether Waves of very great penetrability
Alpha Rays (α) i.e. Helium Atoms
MAGNET
238
226
222
URANIUM
throwing off Alpha Rays becomes, 7500,000,000 years, after a couple of intermediate stages, transformed into
RADIUM, which throwing off the EMANATION of radio active Gas together with the Alpha, Beta & Gamma Rays, becomes in 2500 years, after intermediate stages

PRODUCTION OF RADIUM FROM URANIUM, AND OF POLONIUM FROM RADIUM


Alpha Rays (α) i.e. Helium Atoms
210
206
transformed into POLONIUM which, after throwing off Alpha Rays becomes in about 7 months transformed into an element that is believed to be LEAD
Note. The Rays & Emanation are of course shown in diagram

THIS PICTURE SHOWS HOW THE CHIEF RADIOACTIVE SUBSTANCES DISINTEGRATE

gen in balloons and dirigibles. Helium is, therefore, always found in all minerals containing radioactive elements and when radium is sealed in a glass tube the gradual accumulation of helium can be detected by means of a spectroscope. (See article on "Solar Spectrum" in this volume.)

The beta rays are similar to the cathode rays, which are described in the story of x-rays, except that they travel faster and penetrate farther. The speed of these rays is nearly as great as that of light; but their energy and radio effects are very small compared with the alpha rays. The beta rays are not matter at all in the ordinary sense of the word. They are unit particles of negative electricity, called electrons.

The gamma rays are still more penetrating but less powerful than the beta. They are ether vibrations of the same nature as light and x-rays. They will pierce six inches of lead or one foot of steel.

What is Radioactivity

The alpha and beta particles are the units out of which all atoms are composed. In most elements, the atoms are so strongly built that we have not been able to change their structure. The atoms of radioactive elements, on

the other hand, are so unstable that they are continually falling to pieces. In every radioactive change, an atom shoots off an alpha or beta particle and becomes an atom of a different element. Radioactivity is then a result of spontaneous changes within the atom and exists in but a few elements. Due to the very important discoveries of F. Joliot and Irene Curie-Joliot in 1934, radioactivity can now be induced in most elements. This is accomplished by bombarding the elements with alpha particles, neutrons or positrons. Induced radioactivity is not of long duration.

What becomes of the broken up radium atom

Here is a natural question—what becomes of the atom of radium after it breaks up? We already know that it loses an alpha-particle which is an electrically charged atom of helium having an atomic weight of four. Radium has an atomic weight of 226, so that we would naturally look for an element having an atomic weight of 222. We have not far to seek. Radium is constantly producing a gas, called radium emanation (meaning something thrown off), or "radon," which has just the required atomic weight of 222. This gas is very active, but gradually loses its power and disappears (fifty per cent in about three days) and the radium recovers its activity in about the same time. In thirty days the radon has disappeared, and the radium has regained all the activity that it lost. This is because the radium accumulates a new supply of radon, while the radon that was thrown off breaks up into a series of short-lived products, finally ending in ordinary lead.

How is radium replenished

We have said that half a given amount of radium is broken up in 1700 years. How, then, can there be any left in the world? Even if the world had once been pure radium, there would not now be even the small quantity known to exist, unless it were being replenished from some source. That source is the element uranium. Uranium is constantly producing radium, as shown in our picture. Radium is always found in minerals associated with uranium.

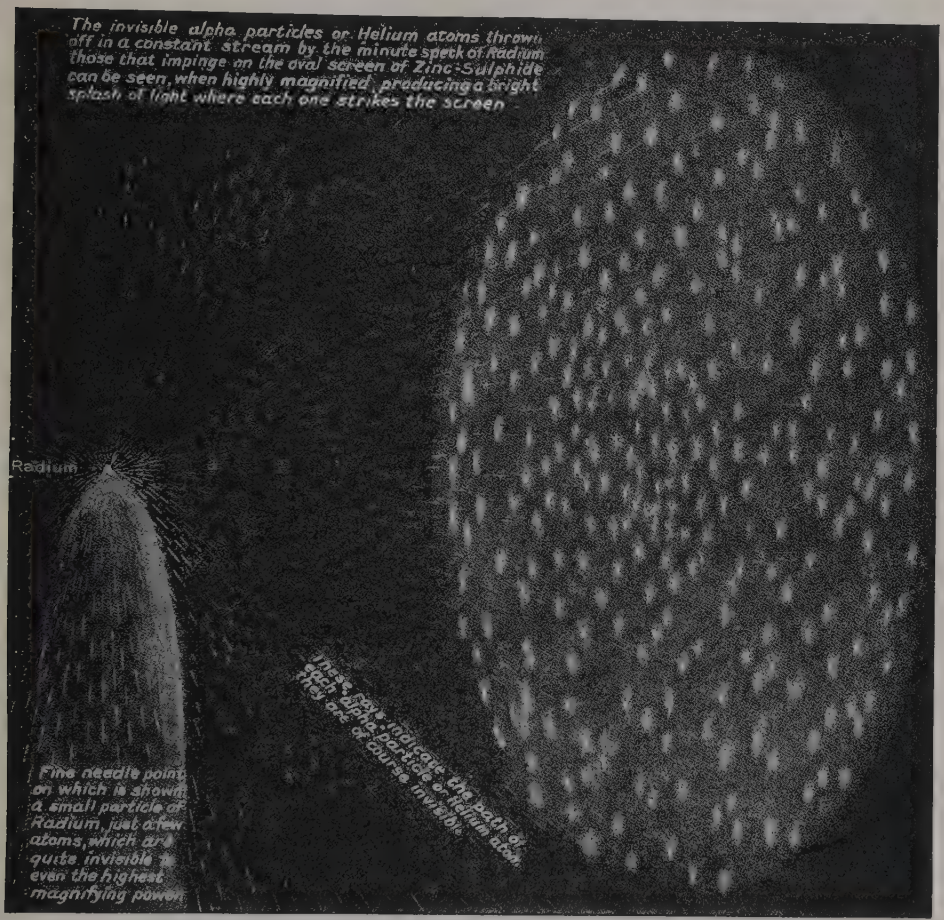
Some healing effects of radium

Just as the bright rays that come to us from the sun are beneficial and stimulating, so also does a moderate amount of radioactivity benefit and stimulate the processes of life. Tests show that in a farmer's field where one-half is treated with a radioactive mineral, other conditions being equal, the crop on the part so treated will grow much faster than the other.

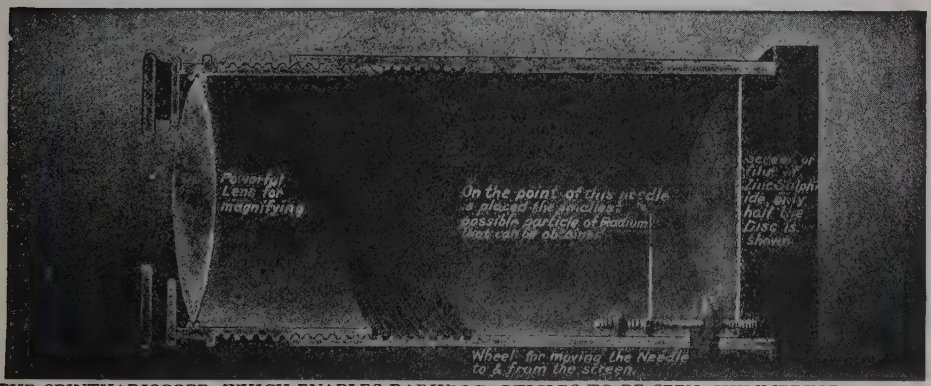
Underground water often contains radioactive material. Hot mineral springs are especially likely to be radioactive. The waters of some of these springs may be helpful because of their radioactivity.

Just as intense sunlight will cause sunburn, and, if concentrated by a lens, destruction without limit, so will too much radioactivity injure one. Happily, diseased cells are more easily destroyed than healthy tissues; and, in many types of cancer, skillful treatment with radium often results in a complete cure. Considerable amounts of radium are needed for such treatment; it must be of high purity and only a specialist can handle the work safely. A tube of high grade radium salt is very deceiving in appearance. It looks as harmless as ordinary table salt, but it may produce a severe burn, and yet cause no sensation at the time. If a tube of radium is held in the hand for several minutes, a soreness will be noticed the next day, and several days

STRIKING VISION OF THE RADIOACTIVITY OF AN ATOM

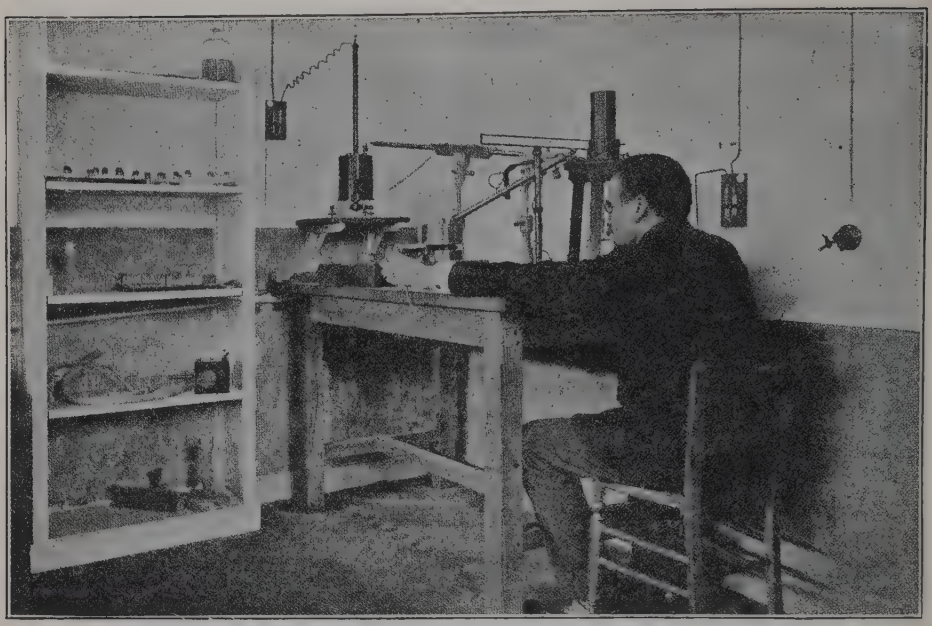

The invisible alpha particles or Helium atoms thrown off in a constant stream by the minute speck of Radium those that impinge on the oval screen of Zinc-Sulphide can be seen, when highly magnified, producing a bright splash of light where each one strikes the screen
Radium
Fine needle point on which is shown a small particle of Radium, just a few atoms, which are quite invisible even the highest magnifying power
These rays indicate the path of each alpha particle or Helium atom they are of course invisible

An invisible speck of radium throwing out invisible atoms that sparkle into sight on a film


Powerful Lens for magnifying
On the point of this needle is placed the smallest possible particle of Radium that can be obtained
Screen of zinc sulphide only half the disc is shown
Wheel for moving the Needle to & from the screen

THE SPINTHARISCOPE, WHICH ENABLES RADIUM PARTICLES TO BE SEEN SHIMMERING CLEARLY

These pictures show the means by which the marvelous energy stored up in radium may be observed. From a speck of radium too small to be seen a stream of helium atoms pours forth, and will do so for many hundred years before the radium ceases to exist. The flying particles fall like hailstones on a zinc sulphide screen or film, splashing on the surface of water. The splash is visible, but the radium itself and flying atoms are not.



MEASURING THE RADIOACTIVITY OF SALTS CONTAINING RADIUM

Although radium was isolated by Madame Curie and her husband in 1910, it is used chiefly in the form of its salts. Previous to 1923 the Colorado deposits were very important, but since that date the Belgian Congo has become the leading producing region. More recently deposits have been found at Great Bear Lake in Canada.

or a week may pass before a definite blister appears; but the burn will be deep and painful and will heal very slowly.

WHAT DOES RADIUM HOLD FOR THE FUTURE

No branch of science holds such promise of rich rewards for the scientist as does radioactivity. It is almost certain that not only the radioactive but all the elements have immense stores of energy locked up in their atoms. How can we use this energy? In radium lies the answer.

In olden times men searched vainly for the Philosopher's Stone, that magic substance which held the secret of perpetual life and the power to change common metals into gold. Perhaps, in radium, we have found that magic element, which, if it will not give us perpetual life, has already done much to banish the terror of one terrible disease. And if it will not turn base metals into gold, it may yet release a source of power more valuable than any amount of precious metal. We are but on the threshold of a greater knowledge of radioactivity. Some day, sooner or later, man will solve the secret of radioactive change; he will direct, control and use the vast store of energy now beneath our very feet. He will do this with radioactivity as he has already done with steam, electrical and chemical power. And when that time comes, man will have advanced as far ahead of our present condition as the present period is advanced beyond the age when man first learned to light a fire and warm his body by it.

SPAN OF THE NEW BRIDGE OVER HELL GATE, NEW YORK

BRIDGES

NO one can say who built the first bridge. Nature herself would no doubt be man's first teacher. Man would find a path across a chasm by clinging to a twisted vine; or he would see a ready-made bridge consisting of a fallen tree-trunk across a stream. Those were the first bridges, and they were the sort which would have to be made for hundreds of years.

One day a genius arose, who dumped high heaps of stone in a line across a stream, and on the top of these placed slabs of slate or stone or fallen trees. Then, a long, long while afterwards, came real bridges. The Romans were the first to learn how to make these. They built splendid bridges on arches, some of which exist today.

A great reform was made in bridge-building by John Rennie, an engineer and architect. It had been customary to make the arches very high, so that the roadway sloped sharply up on one side, and very sharply down on the other. But Rennie made his arches, not like the half of a circle, but like the half of an egg, cut lengthwise.

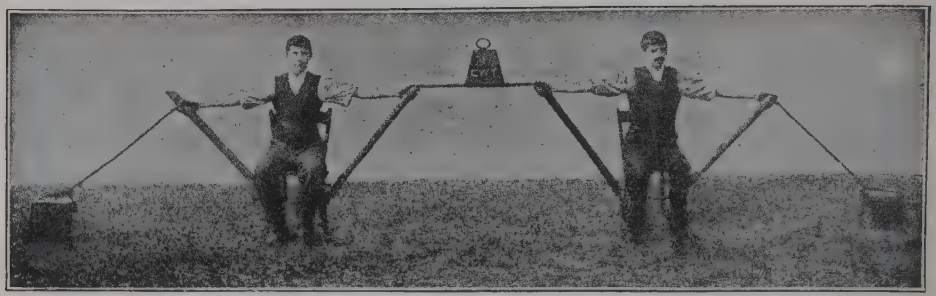
There still exists a famous single-arch bridge of the old type, the famous bridge at Pontypridd, Wales.

When the eighteenth century was drawing to a close, men began to build bridges of cast iron. But engineers soon found that, though cast iron can bear great pressure, it will not bear much pull. It cannot be easily crushed by a weight, but it can soon be snapped by weights which pull at the two ends. So then they used wrought iron, which cannot easily be pulled apart. That served until steel came into use in the nineteenth century.

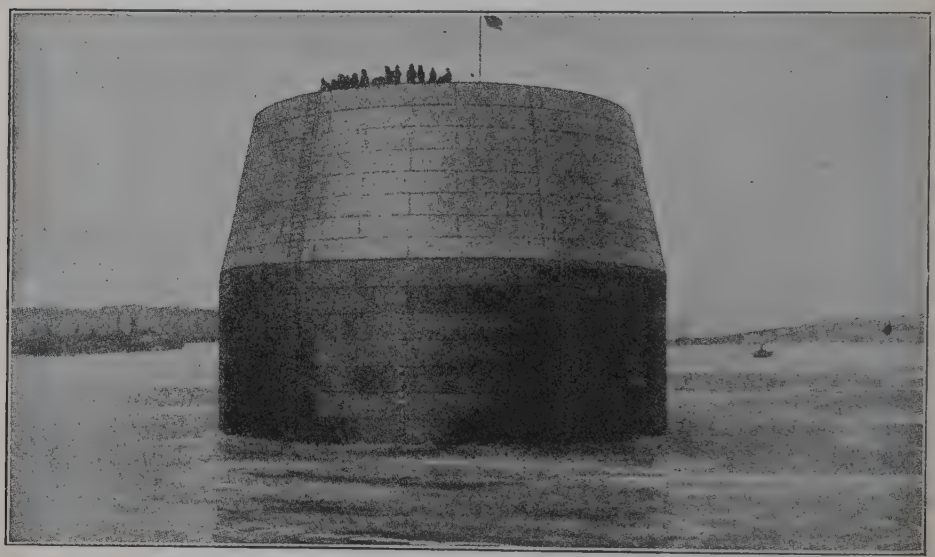
It is over the Hudson River in New York and over the St. Lawrence in Canada that man has gained many notable victories in spanning wide expanses of water with gigantic steel roadways. It must not be forgotten that Great Britain has many fine examples of the bridge-builder's art; the Royal Albert Bridge at Saltash, the Britannia Bridge over the Menai Strait; the Forth Bridge, whose span of 1700 feet has been eclipsed only in recent years, and the Severn are remarkable bridge building feats.

The first great bridge built of wrought iron was the Britannia Bridge, in North Wales. The builder was Robert Stephenson. He made a huge square tube of iron—iron at the top, iron at the sides, iron at the bottom, and through this tube of iron the trains pass. To increase the strength of the bridge he made the

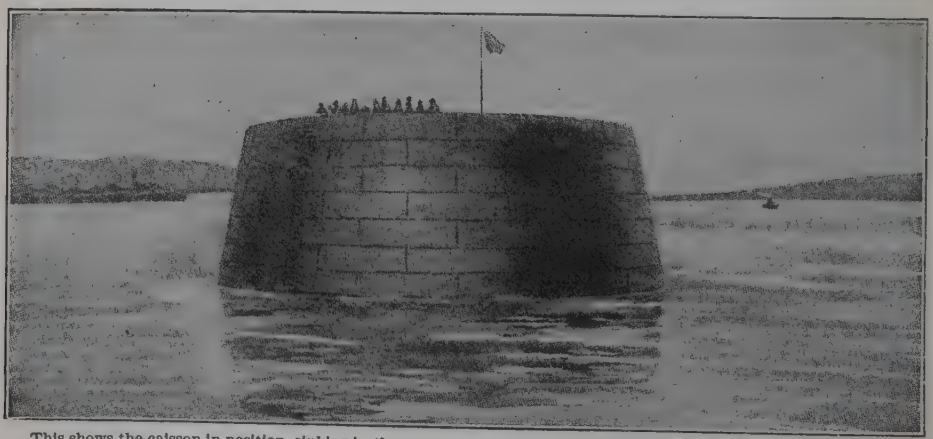
BEGINNING TO BUILD A GREAT BRIDGE



This shows us how the weight of a bridge is distributed; it illustrates what bridge-builders call the cantilever principle. These two men are sitting on chairs, each holding two sticks. The outside sticks are fastened to weights, and cannot move. The inner sticks are fixed to the chairs, and from their tops another stick is stretched, bearing a weight of 112 pounds. Yet the men feel no weight, and they represent two pairs of cantilevers.

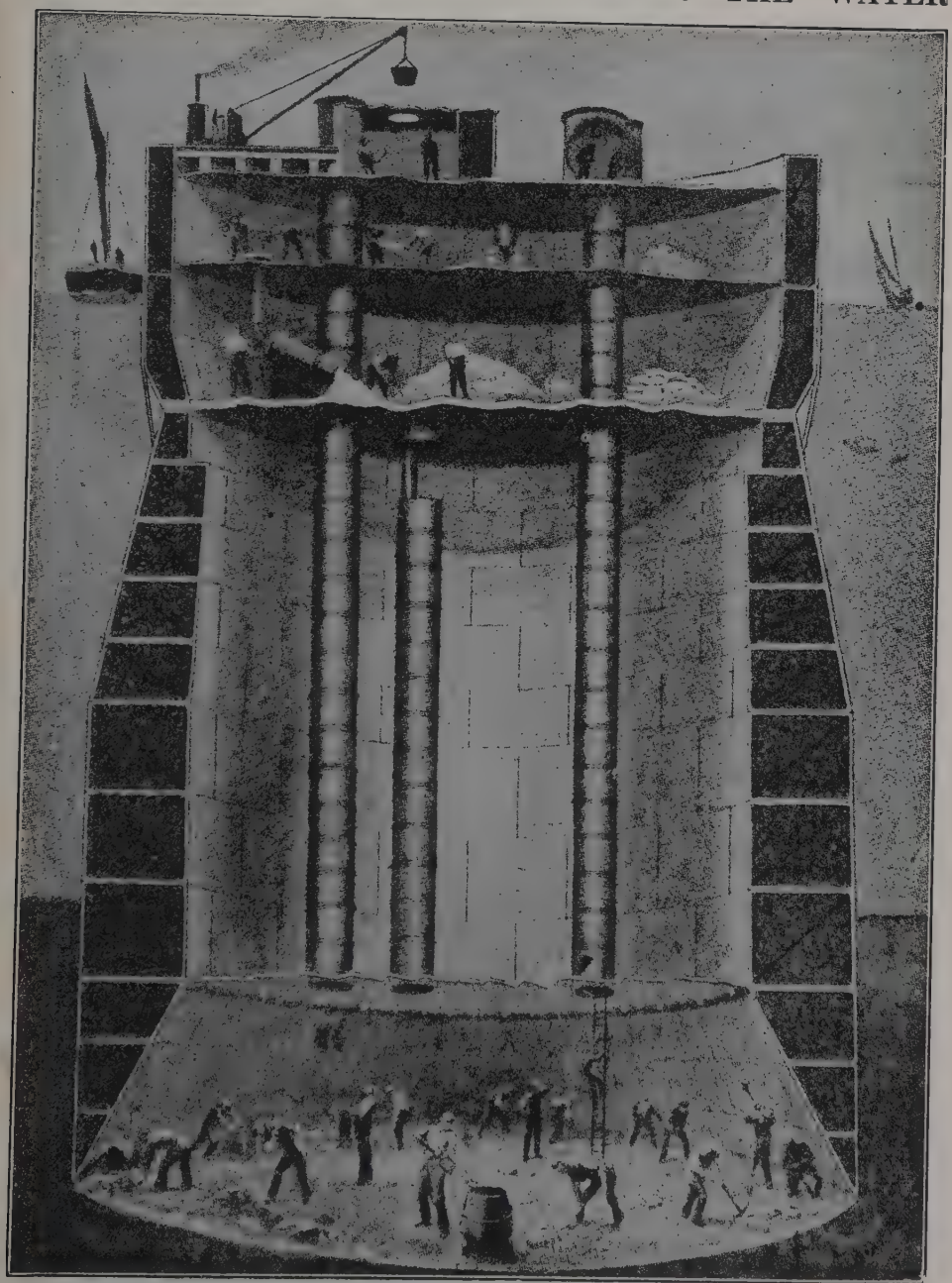


This is a caisson, like a great hollow chamber, inside which men can work to set up the foundations of a bridge. The caisson is here floated into position for the building of the Forth Bridge. The huge steel tubes reach down to the bottom of the water, and men work inside them without danger, as if in a workshop.



This shows the caisson in position, sinking in the water. It is about 70 feet wide at the bottom. Though open at the top, it has water-tight floors inside, and at the bottom there is a chamber 70 feet wide and 7 feet high, lighted by electric lamps, in which the men, breathing air sent down in tubes, can work safely.

THE INTERIOR WORKSHOP UNDER THE WATER



This shows us the inside of a caisson while the men are working. We can see the tubes leading down from the top to the working chamber at the bottom. Inside one tube is a ladder by which the workers climb up and down. Other men bring down material and take up the broken rock which has been dug. Another tube brings down air for the men to breathe. If the bed of the river is muddy the mud is forced away by the compressed air. Water is kept out of the chamber by compressed air which is made to press with greater force than the water. From top to bottom the caisson is 60 feet deep and inside it is like engineering works.

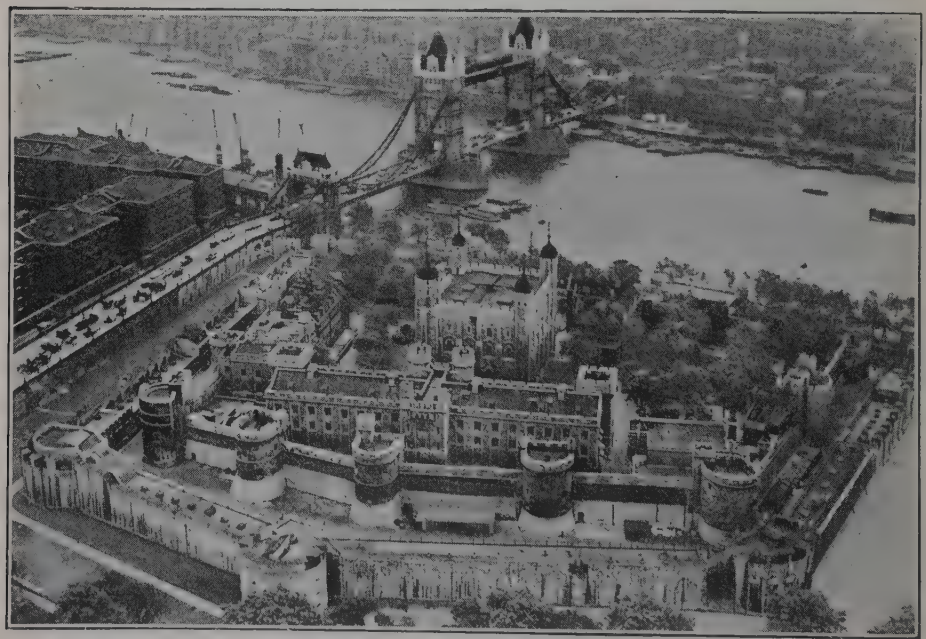
iron at the top and bottom tube-shaped, instead of solid, because it would better stand the pull of the weight.

THE GREAT IRON TUBES IN WHICH THE TRAIN CROSSES THE WATER

These tubes are built on huge columns of masonry, one built on an island half-way across the water, and the others on the land at the sides. As ships were constantly passing, it was impossible to put up great scaffolds on which to build up the ironwork. So Stephenson had the two tubes, nearly 500 yards long, built in four sections on shore. When all was ready the big tubes were floated on many boats, and ferried out to the the towers.

As the tide went out the boats gradually sank, and the tubes, weighing 5000 tons each, came to rest in grooves prepared for them in the masonry. Then the boats were drawn away and the enormous masses of iron were hoisted up to the proper height, 100 feet above the water, by great engines.

An important type of bridge is the great steel cantilever bridge. A cantilever is copied from the oldest of simple bridges. If two trees lean over the water from different sides of a stream we have only to run a plank from the end of one trunk to the end of the other, to make a simple cantilever bridge. That is one way of applying it. The other is to consider the cantilever a bracket. Secured firmly at one end, a bracket will bear a shelf with a heavy weight of books, and the steel cantilevers forming a bridge are merely huge brackets. A good example is the great Forth Bridge, shown in Volume V. It was designed by Sir John Fowler and Sir Benjamin Baker. They had to cross two swift channels of water. There is an island in the middle, but on each side of it there flows a channel of water deep and swift,



Wide World Photo

TOWER BRIDGE, SHOWING THE TOWER OF LONDON IN FOREGROUND

WABASH AVENUE BRIDGE, CHICAGO
Prize-winning Wabash Avenue bridge with Michigan Avenue bridge in the distance.

SYDNEY HARBOR BRIDGE AT NIGHT
Striking night photograph of the new bridge at Sydney, Australia.

and 1700 feet broad. It was impossible to sink piers in these channels, so the central pier was founded on the island, and two others built nearer the shores.

The cantilevers, of which there are three pairs, carry the bridge across the two wide stretches of water. They are each 1360 feet long, and the three, stretching out towards each other, leave a space of 350 feet to be covered between the ends of the first and second, and a similar space between the ends of the second and third. Here ordinary steel girders are used. In order that ships may pass under it, the bridge is made 150 feet above high tide, and its top parts are 361 feet above the water.

The cantilever bridge plan has since been used for many other bridges. One on this plan crosses Niagara at a great height above the water. The cantilever is used in suspension bridges also. Huge columns are erected on land, and from them chains or wire ropes are stretched across the gulf, carrying a roadway.

How kites and rockets are used for building great bridges

A noted suspension bridge in England is at Clifton. This is 702 feet across, and 31 feet wide. It is more than 200 feet above the River Avon, and it is said that the first string attached to the rope which pulled across the cable was sent over by a kite.

A more unusual way was adopted for starting the great bridge across the River Zambesi, in South Africa. The bridge, then the highest in the world, 400 feet above the water, extends from cliff to cliff; so they had to fire a rocket fastened to the end of a cord. The rocket took the cord across, the cord was used for hauling across a wire, and the wire was used to pull over a small cable. On this a truck crossed carrying the main cable of the bridge, which is 200 yards long, and the greatest engineering wonder in South Africa.

Bridges that open in the middle

The Tower Bridge, in London, is 800 feet long. When a ship is too high to pass under, great machines cause the roadway to open in the middle. The two halves are pulled up, working on enormous hinges, and the ship passes through.

A well-known example of a double-deck bascule bridge is the Michigan Avenue Bridge in Chicago.

The Saltash Bridge which spans the Tamar is 2200 feet long, the two main spans over the river being each 455 feet long. Obtaining the foundations for the pier was a particularly dangerous piece of work. A huge caisson was sunk in midstream, in which, provided with compressed air, the men toiled for two years. In the winter storms the unwieldy cylinder rocked so violently despite its heavy weights and chains, that leakages occurred, and it was only by beating hasty retreats that the men escaped drowning. The two gigantic spans were built complete upon the shore and floated out into position, and then gradually raised.

New York city bridges

For some of the very best examples of the bridge-builders' skill we may go to New York. Here, in space of a single square mile we have three notable examples of suspension bridges —the Brooklyn, the Manhattan, and the Williamsburg Bridges, while some three miles above the last-named there now towers the Queensboro Bridge. They are rightly regarded as among the wonders of the engineering world. They vary from 6000 to 7000 feet in length, with a central span of from 1400 to 1500 feet and carry four tracks for railways, two

or more for cars, a couple of roadways for vehicles, and various sidewalks for pedestrians, while the towers reach a height of 300 feet and more above the water, the aerial pathway being some 130 feet above the surface of the river.

The Brooklyn Bridge took thirteen years to build, and cost $16,000,000. It was designed by John A. Roebling, the builder of the Niagara Falls suspension bridge and others. While engaged in the preliminary work he met his death. He was succeeded by his son, William A. Roebling, who in turn was injured by a fire in one of the caissons and became a permanent invalid. He was removed to a residence on the heights of Brooklyn, where, with indomitable resolution, he watched the details of construction from his window by the aid of a telescope, and, assisted by his wife, directed the progress of the work to its successful completion.

It is impossible to point to any large bridge the erection of which has not demanded its toll of human life. The Queensboro Bridge referred to before cost 67 lives; some 70 brave men were killed in the Quebec disaster in 1907, when that partially completed structure suddenly collapsed after three years had been spent upon it, and some 15,000 tons of steelwork had been placed and bolted in position.

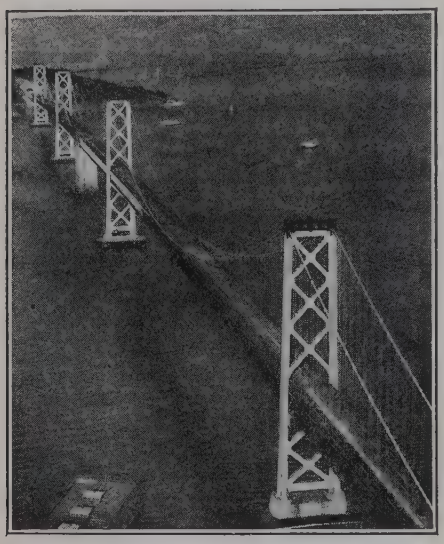
With its approaches the Brooklyn Bridge is a mile and 660 feet in length. There is a central river span of 1595½ feet from tower to tower, two land spans from towers to anchorages, and the land approach on either side. This aerial roadway is held in place by cables, four in number. They each contain 5296 steel wires reaching from anchorage to anchorage, on either side of the river, a distance of 3752 feet. This gives a total of 14,000 miles of wire. Each cable has a diameter of 15¾ inches, and a breaking strain of about 12,000 tons. The roadway is 85 feet wide. The engineers declare that the "natural life" of the bridge is 20,000 years.

After the Brooklyn Bridge came the Williamsburg structure, which was erected in seven years at a cost of $20,000,000. It has a total length of a mile and 1920 feet, including a main span of 1600 feet, and two shore spans of 600 feet. The four cables are each 19 inches in diameter, and are built up of 37 strands, each strand containing 208 wires, each 3020 feet long. Figure this out and we get 19,000 miles of wire, possessing a weight of 5000 tons. The towers of this bridge rise 335 feet above the water level, and are built of steel. Somewhat similar in design is the Manhattan Bridge. The wire consumed here totals 23,000 miles, while no less than 40,000 tons of steel were used in the erection of this single aerial pathway.

More wonderful still, from an engineering point of view, is the Queensboro Bridge, an upper East River structure. In length and weight it rivals and in carrying capacity also surpasses the famous Forth Bridge. Its trusses are the heaviest ever built. There are two main spans of 1182 and 984 feet respectively, springing from two piers erected on a mid-channel island. From end to end the bridge measures 3725 feet, and together with the approaches, the total length is swelled to 7358 feet.

Hell Gate Bridge over the East River is one of the heaviest steel bridges in the world. The stupendous engineering project that produced this bridge made real the dream of a direct through all-rail route between New England and the South and West. For the first time all the important cities of the Atlantic seaboard are connected by a continuous, direct, all-rail

coastal line. The strategic importance of this line for military movements in time of national defense can not be overestimated, although it is for the



SAN FRANCISCO-OAKLAND BAY BRIDGE

regular carrying of passengers and freight that we trust it will always be used.

Hell Gate Bridge (see illustration on page 427), is of span and viaduct construction, and between its mighty towers lie four tracks. One of the narrowest sections of the East River was chosen for the crossing and the two gigantic towers rise 240 feet from the ground. The towers are bedded in the solid rock, which is from 60 to 100 feet below the surface.

At the level of the tracks, great arches, wide enough to permit the laying of a standard four-track railroad through them, rise in graceful proportions in the centers of the towers. Smaller archways are cut to permit the passage through the tower of footways on either side of the bridge. There are also arches cut through the side walls of the towers just above the track level. The towers rise 95 feet above it and are surmounted by an artistic balustrade.

From the two main towers the main arch springs in one leap across a thousand feet of water, holding suspended from its great arms the roadway of riveted steel and deep concrete basins in which is laid a stone-ballasted four-tracked railroad.

The largest bridge in the world

On November 12, 1936, traffic began to speed over the world's largest bridge, the San Francisco-Oakland Bay Bridge. It is 8¼ miles long from the end of the western approach to the end of the eastern approach. The bridge proper, including the island crossing, is 23,000 feet long, or about 4½ miles. It is a double-deck structure with six lanes of automobile traffic on the upper deck and three lanes of tracks plus two interurban tracks on the lower deck. It cost $77,000,000.

The western half of this great bridge is really two complete suspension bridges anchored midway between San Francisco and Yerba Buena Island to a concrete center anchorage. Through Yerba Buena Island the largest bore tunnel in the world has been made.

The San Francisco-Oakland Bay Bridge uses enough cable wire to encircle the earth almost three times. The concrete and reinforcing steel is enough to rebuild all of the large office buildings of downtown San Francisco. The timber would build 3,000 five-room dwellings.

Bridging the golden gate

Surpassing all other suspension bridges, the daring construction known as the Golden Gate Bridge at San Francisco with its span of 4,200 feet, open to traffic in 1937, is a climax of engineering achievement. Its total length is 9,200 feet and its cost is $33,500,000.

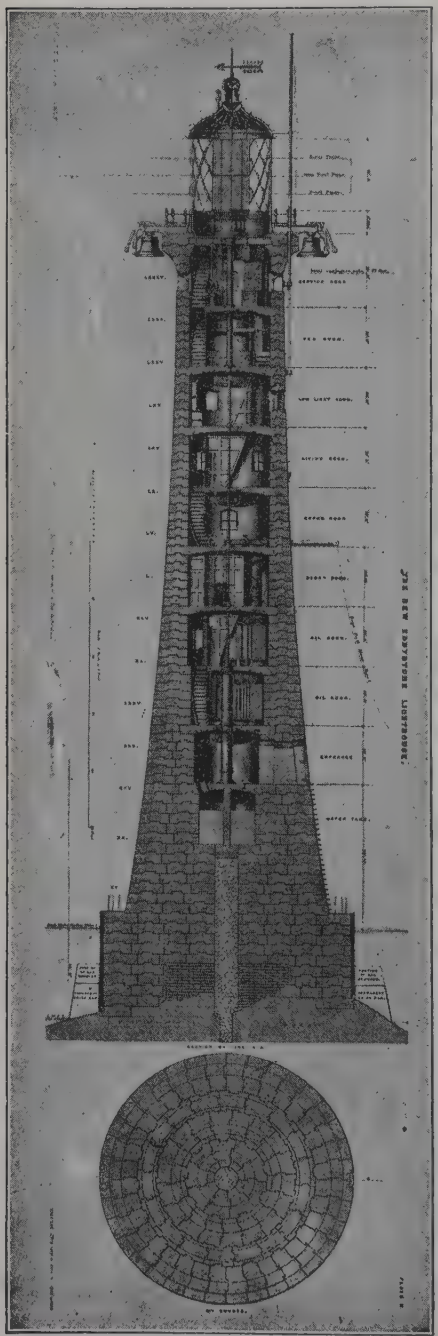
EDDYSTONE LIGHTHOUSE, ENGLISH CHANNEL

LIGHTHOUSES

EVER since man began to navigate the waters he has endeavored to light them at night. This he accomplishes today by the erection of beacons or towers upon the shore and rocks, from the summit of which a beam of light is automatically flashed over the ocean, and also by means of lightships and illuminated buoys. How necessary these lights are to guide and warn the mariner is obvious by the returns of wrecks.

The father of the modern lighthouse was undoubtedly the ancient Pharos of Alexandria, in Egypt, one of the seven wonders of the world. It was built by Ptolemy Philadelphus (283—247 B. C.), on a small island at the entrance to the harbor, connected by a causeway with the mainland. The Pharos cost 800 talents; if these were silver talents—as most likely they were—that would be equal to $850,000, the largest sum ever expended upon a single lighthouse. The structure had a base of some 400 feet, and towered 450 feet above sea-level. As the whole was built of white marble, the edifice must have been at once elegant and impressive. At the summit fires were kept burning to direct the mariner through the tortuous entrance of the bay. It is recorded by some of the ancients that the flame of the Pharos could be discerned 100 miles at sea. This, of course, is an exaggeration, as the most up-to-date light of modern times, with all the latest inventions for increasing its intensity, is only visible thirty miles out. It is doubtful if the smoky gleams of the ancient Pharos were

INTERIOR VIEW OF EDDYSTONE LIGHTHOUSE



This picture shows the interior structure and arrangement of one of the famous beacons of the world.

seen twenty or twenty-five miles on a clear night.

CHURCH, PALACE AND BEACON

The Romans built many lighthouses, and it is said that several exceeded in splendor and magnificence the famous Pharos, but not one of them remains. The earliest example extant of a lighthouse is the famous Tower of Cordouan, France, which dates from 805 A. D. but has been rebuilt on several occasions. The present edifice, which was begun by M. Louis de Foix, in 1584, is certainly one of the most remarkable edifices in the world. This lighthouse (originally 180, now 207 feet in height), is beacon, church, and royal residence in one, many of the French kings having occupied it.

Until the time of John Smeaton, who invented the dovetailed stone tower, lighthouses, with a few exceptions, were built of wood. It was Smeaton's success in placing a stone edifice on the dreaded Eddystone Rocks, in the eighteenth century, which gave an impetus to lighthouse building.

Smeaton's first tower of solid stone braved the elements on the Eddystone for 123 years, when it was dismantled and reerected on the Hoe at Plymouth, and another tower put up in its place on an adjoining reef. The reason for the removal of the lighthouse was that the rock on which it stood had been worn away by the action of the sea. Long before this occurred, however, it had been demonstrated that the stone tower was the best device for equipping a wave-washed rock with a light. Stone towers sprang into existence on dreary rocks around the British Isles and in America.

There are now about 260 lighthouses around the coasts of Great Britain alone, and 530, having resident keepers, within the jurisdiction of the United States.

THE PRESENT BOSTON LIGHT
Built in 1783 by Massachusetts and ceded to the United States in 1790

First American lighthouse

The first lighthouse on the American continent was built by the province of Massachusetts, 1715-16, on an island at the entrance to Boston harbor. The light was supported by light dues of one penny per ton, levied by the receiver of impost at Boston on all incoming and outgoing vessels except coasters. This lighthouse was an object of attack during the early part of the Revolutionary War, and was burned by the Americans and finally blown up by the British in 1776. A new lighthouse on the same site was built in 1783 by Massachusetts, and this, with various alterations, is the present Boston light.

Although candles and even coal fires have been used in lighthouse illumination in England to a much later date, Boston light was probably illuminated from the first by oil lamps. In 1789 the light was produced by 16 lamps in groups of 4. Crude lenses and reflectors were fitted in 1811, and also revolving mechanism, it having previously been a fixed light. In 1838 Boston light is described as "a revolving light, consisting of 14 Argand lamps, with parabolic reflectors," the lamps being "of about the volume of similar lamps in family use." In 1839 large reflectors 21 inches in diameter were fitted to this light. Boston light was provided with a Fresnel lens in 1859.

Apparently a great gun was the only fog signal at this station until about 1852, when a fog-bell was installed. A mechanical striking bell was installed in 1869, in 1872 a fog trumpet, and in 1887 an air siren.

The oldest of the existing lighthouse structures in this country is the tower at Sandy Hook, New York, built in 1764. This massive structure of stone and brick has walls seven feet thick at the base. The lighthouse at Cape Henlopen, Delaware, similar in design, was built in the same year. It was destroyed in 1926.

SANDY HOOK LIGHTHOUSE, NEW YORK HARBOR

This rugged old lighthouse, built in 1764, is the oldest existing lighthouse tower in this country. The great walls at the base are seven feet thick.

LOCATION AND CONSTRUCTION OF LIGHTHOUSES

The first-class light and fog-signal stations are located at the more prominent and dangerous points along the seaboard, and on a well-lighted coast such stations should be sufficiently close that a coasting vessel may always be in sight of a light. The smaller lights are placed to mark harbors, inside channels, and dangers. Along the navigable rivers numerous post lights are maintained to indicate the channels.

For New York harbor and immediate approaches alone, over 400 aids to navigation are required, including 74 shore lights, two light vessels, and 53 lighted buoys; there are 215 buoys of all classes and 86 fog signals, including sounding buoys.

At the principal stations provision is made either in the tower or in separate buildings for the mechanical equipment connected with light and fog signal, for storage of oil and supplies, for quarters for keepers and their families, boats, etc.

Various materials have been employed in lighthouse construction—stone, brick, iron, steel, concrete, reinforced concrete, and wood; in new work, however, the latter is now little used because of the desirability of permanency.

WONDERFUL SEA-SWEPT LIGHTHOUSES

Lighthouse construction on the land is usually comparatively simple, except when there is difficulty of access to the site. But often it is important for the protection of shipping that lighthouses be erected either on rocks or reefs

exposed to the sea or actually in the water, on sand or rock bottom. Such work has called forth the greatest skill of engineers.

Numerous types of construction have been used. Where the foundation is exposed, even at the lowest tides, masonry towers have been, with great labor and often danger, fitted to the bed-rock; otherwise the structure has been erected on iron piles driven, screwed, or pumped into the sand or coral, or on caissons floated to the site and set on the bottom or sunk deeper by the pneumatic process, or by the use of coffer-dams, within which the masonry tower has been erected; smaller structures have been placed on rip-rap foundations.

The earliest example now existing of a sea-swept lighthouse is the beautiful tower of Cordouan, built in 1584 to 1611, on a rock in the sea at the mouth of the Gironde, on the west coast of France. This lighthouse has since been altered and raised in height. The original structure was elaborately decorated, and one floor was occupied by a chapel.

The beautiful lighthouse on the coast of France, Phare de Cordouan, completed in 1611 and since altered: the oldest sea-swept lighthouse now in existence

The most famous of the sea-swept lighthouses is the Eddystone, 13 miles from Plymouth harbor, England. This was completed in 1699, after four years of work. During the first year all that was accomplished was drilling 12 holes in the rock and fastening irons in them. This lighthouse, with the keepers and the engineer who built it, disappeared in the great storm of November, 1703, and since that time three other lighthouses have in succession been erected on the Eddystone.

Minots ledge light

The earliest lighthouse built in this country in a dangerous position, exposed to the open ocean, was that on Minots Ledge, a reef off Boston harbor which had long been a terror to mariners.

There was a great gale in April, 1851. "The light on the Minot was last seen from Cohasset on Wednesday night at 10 o'clock. At 1 o'clock Thursday morning, the 17th, the lighthouse bell was heard on shore, one and one-half miles distant; and this being the hour of high water, or rather the turn of the tide, when from the opposition of the wind and the tide it is supposed that the sea was at its very highest mark; and it was at that hour, it is generally believed, that the lighthouse was destroyed; at daylight nothing of it was visible from shore, and hence it is most probable it was overthrown at or about the hour named." Two keepers were in the tower and were lost, and this extract from the official report tells the story of one of the great lighthouse tragedies.

The present massive stone lighthouse was built on the same site on Minots Ledge, commenced in 1855 and completed in 1860. It ranks among the

difficult lighthouse engineering works of the world. During the first summer only 130 working hours were obtained on the rock, and after three years' work only four stones of the foundation were laid. The reef rock was prepared to fit the stones of the lower courses and the latter were cut to interlock. Dwellings for the keepers' families were built on the shore, accommodations for the men only being provided in the tower.

Longfellow visited Minots light in 1871, and in a letter thus describes it: "The lighthouse rises out of the sea like a beautiful stone cannon, mouth upward, belching forth only friendly fires."

WHITE SHOAL LIGHT

White Shoal, a dangerous spot in Lake Michigan, at the entrance to the Straits of Mackinac, was marked for 19 years by a light vessel anchored over it. On account of the ice, this vessel could not be kept on the station during a portion of the season of navigation in the spring and fall. As the unmarked shoal was a serious menace to navigation at these seasons, an appropriation was made for building a lighthouse, and this was completed in 1911 at a cost of $225,000.

A timber crib 72 feet square and 18 feet high was built on shore and floated out to the site, where the depth of water was 22 feet. The bottom, which is of coarse gravel, was covered with 2 feet of rock, and the crib was filled with stone and sunk. Above this was built a concrete pier, which supports the lighthouse.

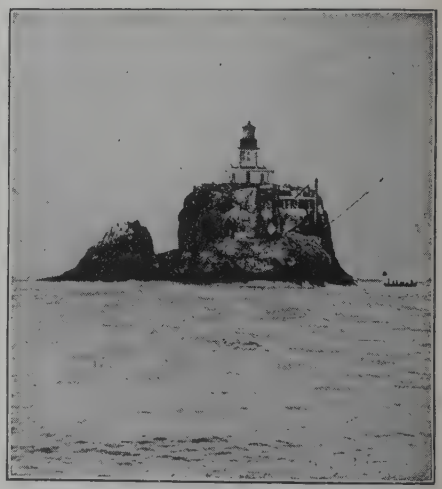
The light is of 3,000,000 candle power, flashing white every 15 seconds. The fog signal now in use is a compressed air whistle.

HOW MANY OF THE SMALLER STATIONS ARE PROTECTED

An electric light, flashing automatically at regular intervals, and operating without attention over long periods with current from primary cells, has been installed at a number of minor stations in the United States.

TILLAMOOK ROCK—ONE OF THE MOST EXPOSED IN THE WORLD

Two lighthouses involving great difficulties have been built on rocky islets of the Pacific coast—Tillamook Rock, completed in 1881, and St. George Reef in 1891. Tillamook is a high, precipitous rock south of the Columbia River and about a mile from shore. It is exposed to the sweep of the Pacific Ocean. Landing on the rock



THE TILLAMOOK ROCK LIGHT COMPLETED
The seas here are terrific. In October, 1934, waves broke sixteen panes of the lantern 132 feet above the sea.

was very dangerous, and the foreman was drowned the first day a working party was landed. There was serious difficulty in providing any protection on the rock for the workmen. It was necessary to blast off the top of the rock to secure sufficient room for the lighthouse.

This light station is one of the most exposed in the world. The tower is 136 feet above high water, but the keepers reported that in a storm in 1887 the seas broke over the building, some going above the tower, and serious damage was done. In another

storm, October 21 to 25, 1934, rock fragments weighing sixty pounds were carried by the waves through the plate glass of the lantern.

St. George Reef Light, California

St. George Reef light is built on a rock lying 6 miles off the northern coast of California. The rock was so exposed and swept by the seas that workmen could not safely live upon it, and it was necessary to moor a schooner near the rock to provide quarters for the men, who were transported back and forth by a traveler on a cable. The total cost of the work at St. George Reef was about $712,000, making it the most expensive lighthouse that has been built in this country. These two exposed light stations on the Pacific coast are the only ones having five keepers.

Famous Shore Lights

The tallest light tower in the United States is that at Cape Hatteras, on the low-lying coast of North Carolina, which is 200 feet from base to top of lantern. The highest light, however, is that at Cape Mendocino, on the coast of California, which is shown 422 feet above high water; it is on a cliff, the lighthouse itself being only 20 feet in height.

Troubles from Ice, Birds, and Sand

Sand creates difficulties at some light stations located among dunes or shifting wastes of sand. At one lighthouse the sand driven by the wind cut deeply into the wood framing of the keepers' dwellings and ground the window glass so that it was no longer transparent; but the lantern of the light was too high to be so affected.

Even the flying birds make trouble at lighthouses, as the brilliant light so attracts them that they will fly directly for it, and striking the heavy glass of the lantern are killed.

From Wood Fires and Candles to Oil Vapor and Electric Lamps

The early lighthouses were lighted by wood or coal fires burned in open braziers, and later by candles inclosed

THE TALLEST LIGHT TOWER OF THIS COUNTRY, 200 FEET HIGH: THE CAPE HATTERAS LIGHTHOUSE, NORTH CAROLINA

The spiral painting is to furnish a distinctive day-mark to mariners. "A light must be about 200 feet above the water to be seen from the deck of a vessel 20 nautical miles distant; beyond that distance the curvature of the earth would prevent a light at this elevation being seen."

in lanterns; the resulting light was necessarily weak and fitful, and a large part was lost by being diffused in directions of no use to mariners. Oil lamps were early introduced in this country and at the present time lamps with from one to five concentric wicks, and burning a high grade of kerosene oil, are used in many lighthouses. For the more important oil lights the incandescent oil vapor lamp is now used. In this lamp the oil is heated and then vaporized, and is burned mixed with air under a mantle which is made incandescent.

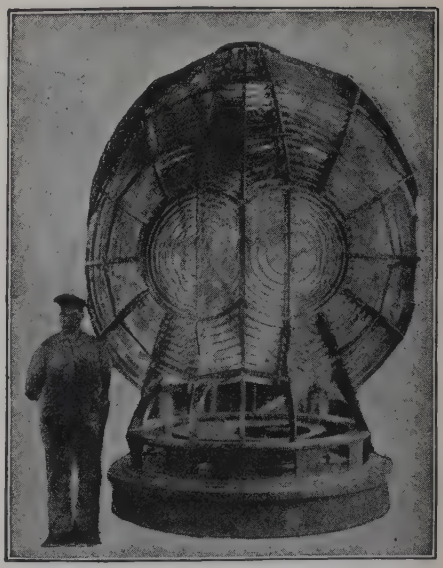
Electric lights are now used at a number of light stations, current being generated at the station when commercial current cannot be obtained from the outside.

The important light at Navesink, on the highlands just south of New York harbor, is the most powerful coast light in the United States. This light shows each five seconds a flash of three-tenths second of about 9,000,000 candle power. Although, on account of the curvature of the earth, the light itself cannot be seen more than 22 miles, its beam has been reported to have been observed in the sky at a distance of 70 nautical miles.

Powerful Reflectors, Lenses, and Prisms Are Used

In order to increase the effectiveness of illumination, reflectors, lenses, and prisms are used to concentrate the light and throw it out either in a plane around the horizon or in a beam or limited arc, where it will be most useful.

With the most complete lenses about 60 per cent of the light is rendered useful, the balance being lost at the top and bottom and by absorption of the glass of the lens and the lantern. The largest lens in service is that at Makapuu Point light, Hawaii, which is 8¾ feet in diameter.



A BEAUTIFUL GLASS LENS AND MOUNTING, COSTING $12,000, BUILT IN FRANCE FOR THE KILAUEA LIGHTHOUSE IN THE HAWAIIAN ISLANDS, COMPLETED IN 1917

This is the landfall light approaching the islands from Japan. The light gives a double flash of 540,000 candle power every 10 seconds. The lens and mounting "weighs nearly 4 tons and turns on a mercury float, making a complete revolution every 20 seconds and giving a double flash of about 540,000 candle power every 10 seconds. The light is sufficiently powerful to be visible 35 miles, but because of the earth's curvature it can be seen only 25 miles."

The most powerful flashing lights are arranged to have the entire lens revolve, the beam from each panel of the lens appearing as a flash as it sweeps past the observer. To obtain rapid and smooth revolution, the lens is mounted on a mercury float, and a lens weighing, with fittings, as much as 7 tons may make a complete revolution in 30 seconds.

A recent example is the lens for Kilauea light station, Hawaiian Islands.

Buoys

Floating buoys are efficient and relatively inexpensive aids to navigation. They are used to mark dangers —as shoals, rocks, or wrecks—to indicate the limits of navigable channels, or to show the approach to a channel. They vary in character

according to their purpose or the distance at which they should be seen. The simpler forms are the wooden and iron spar buoys, and iron can and nun buoys. To warn in thick weather or nights, buoys with bells or whistles, actuated by sea motion are used; others actuated by compressed gas sound a bell.

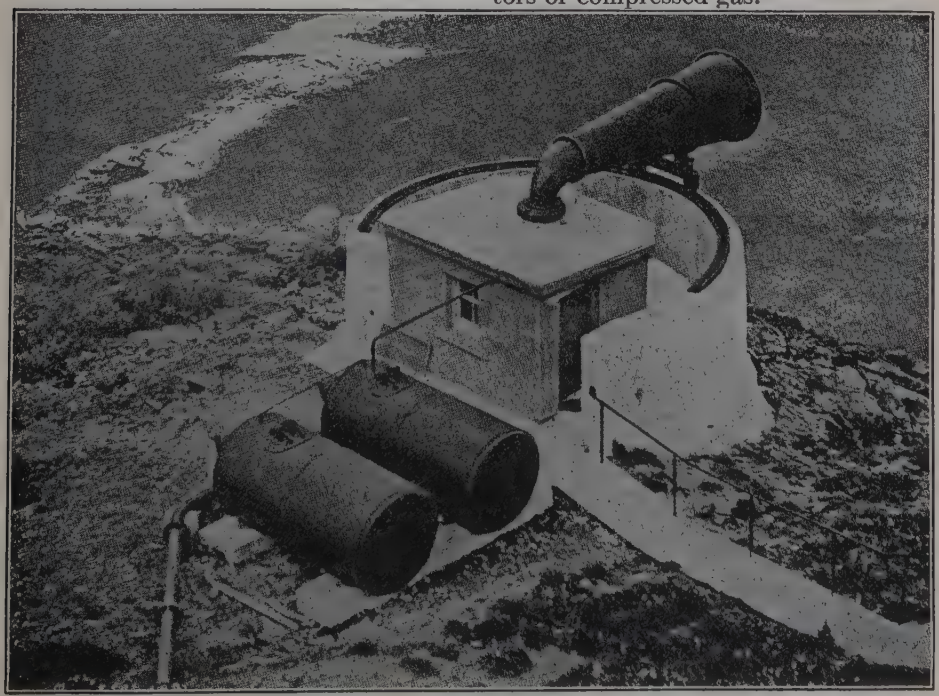
Many important buoys are lighted now by means of acetylene gas compressed in tanks that are placed in the buoy.

The buoy off the entrance to Ambrose Channel, New York harbor, at a height of 28 feet above the water, shows a light of 390 candle power, occulting every 10 seconds and visible 11 miles. This buoy recently burned for one year and four months without recharging. The buoy is nearly sixty feet in length and weighs more than seventeen tons.

Fog signals

The most powerful coast lights may be rendered of little or no use to navigation by thick fog or rain. To assist vessels under such conditions, making their course more safe or allowing them to proceed, fog signals of many sorts have been established. Of these the bell is the most common.

The fog signals now used in the United States, consist of sirens, whistles, diaphones, tyfons, reed trumpets, aerial bells, submarine bells and oscillators. Sirens, diaphones, tyfons and whistles are operated by compressed air or steam, trumpets by compressed air, and oscillators by electricity. To furnish air, compressors driven by internal combustion engines are used, and for steam signals boilers are employed. The larger fog bells, up to 4000 pounds, have hammers actuated by a weight and clockwork—by electric motors or compressed gas.



There is nothing sailors dread more than a fog, when lights cannot be seen. The sailors are like men deprived of their sight. Then it is that the foghorns begin to sound. A foghorn is often heard for twenty miles, but in some weathers only for one or two miles. This picture shows the Bass Rock foghorn, on the east coast of Scotland.

THE RACINE REEF LIGHTHOUSE, IN LAKE MICHIGAN, COVERED WITH ICE

Winter seriously increases the work of maintaining aids to navigation; the spray or sleet freezing may completely envelop the tower in ice, obscuring the light until the lantern is cleared. In northern waters, where there is floating ice, many of the gas buoys must be removed in winter and replaced by spar buoys, over which the ice may pass without serious damage to the buoy. The spray freezes to bell buoys sometimes until the weight of ice overturns them.

Radio fog signals are now established at more than 100 of the shore light stations and on light vessels in the United States and foreign countries. During thick weather each of these sends automatically a characteristic radio call by which the station is identified and by which a vessel equipped with a radio compass, or direction finder, may determine its bearing from the station although it may not be visible. The direction finder also enables a vessel to obtain the bearing of another vessel sending radio signals.

Besides the above, there are various noise-making buoys; bells and also whistles frequently are attached to buoys and are made to sound by the movement of the buoy due to the sea. Nearly all fog signals excepting those on buoys are operated to sound a characteristic signal so that they may be distinguished, there being a succession of blasts or groups of blasts or strokes at regular time intervals, which are made known for each station. Even adjacent buoys are differentiated by the use of whistles and bells and by variation of tone.

Submarine Bells

Submarine bells were first regularly employed as fog signals in the United States in 1906. The bell is suspended in the water from a light vessel to a depth of 25 to 30 feet and is operated by compressed air.

The number of submarine bells has been materially decreased in recent years on account of the widespread use of radiobeacons and radio signals in navigation. For the same reason, submarine oscillators, although more efficient than submarine bells, are not being introduced in the Lighthouse Service. Submarine bells now represent less than 1 per cent of our fog signals.

AN UNATTENDED FLASHING GAS LIGHT ON RICHARDSON'S ROCK, CALIFORNIA

This light will flash every three seconds for seven months before it requires another charge of gas. This would be a difficult and expensive site on which to establish a regular lighthouse with keeper's quarters.

AIDS TO AIR NAVIGATION

The lighting and marking of airways formerly associated with the Lighthouse Service is now under the Bureau of Air Commerce. At the beginning of 1933, aids to air navigation installed and operated on the federal Airway System totaled about 20,000 miles. These include (1) intermediate landing fields at intervals of about 50 miles to provide emergency landings, (2) field lighting systems to make these usable during the hours of darkness, (3) beacon lights to mark the location of fields and also the airway course between landing fields and airports, (4) radio communication stations to broadcast weather reports and other information to aircraft in flight, (5) radio range beacons to provide courses which may be followed accurately when weather conditions cut off all view of landmarks or beacon lights, (6) radio marker beacons to provide a landmark substitute for use in "blind" flying, and (7) a teletype weather reporting and communications system for the collection and dissemination of weather information and facsimile transmission of weather maps at four-hour intervals.

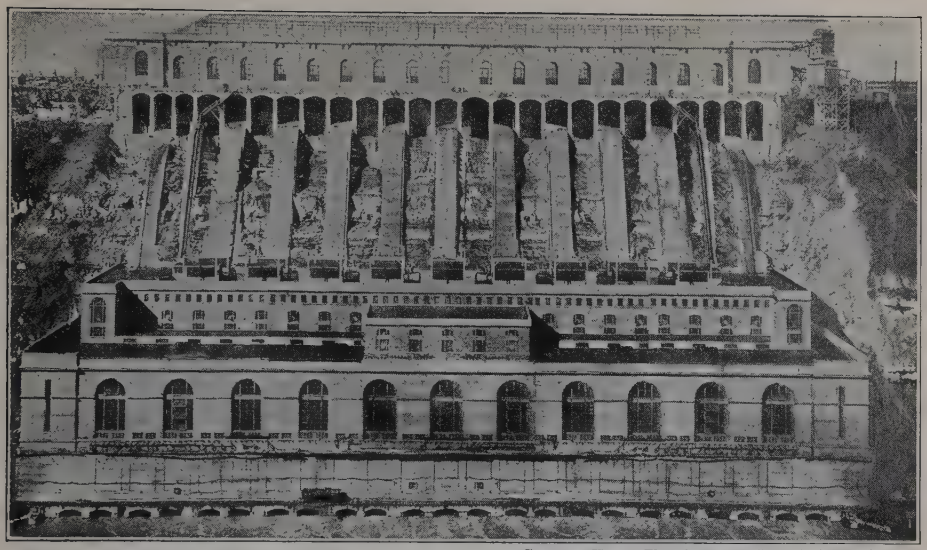
Courtesy U. S. Department of Commerce.

BEACON FOR NAVIGATORS OF THE AIR

Beacon light and caretaker's house at a Department of Commerce intermediate landing field. This is a 24-inch single-ended light.

THE WORLD'S GREATEST WATERFALLS AND GREATEST SOURCE OF POWER

BIRDSEYE VIEW OF NIAGARA FALLS SHOWING POWER DEVELOPMENT ON CANADIAN SIDE



Courtesy Hydro-Electric Power Commission of Ontario

QUEENSTON-CHIPPAWA POWER DEVELOPMENT—NIAGARA RIVER

The great power house in the gorge of the Niagara River at Queenston, Ontario. A composite picture showing the completed power house with screen house on top of the cliff and concrete-covered steel pipe lines leading water to turbines, also transmission line structures carrying power lines from the roof of the power house over the screen house.

POWER AT NIAGARA FALLS

WHEN we wish to say how insignificant a thing is, and how little work it can accomplish, we often say it is like "a drop in the ocean." And yet the power in the drop of water, added to the power in countless other drops, is vast and can accomplish a prodigious amount of work.

The power of falling water is no new discovery. Solomon had discovered this power when he wrote, "A continual dropping weareth away stone." But it is only in recent times that men are making large use of the fact that water may have stored up in it energy enough to light our cities and drive our machinery.

Engineers look forward confidently to the day when electricity will be almost universally used for the distribution of power. Those countries that have large waterfalls and swiftly-flowing rivers that can be utilized for producing electricity are especially favored as, in large developments, power obtained from falling water is usually cheaper than that obtained from coal by means of steam plants.

If you put your finger under the water faucet and then turn on the water, you notice that the water presses with such force against the finger that it cannot be held in, but spurts out all around. What, then, must be the accumulated force of a mighty mass of water falling from a great height?

The world over men are now harnessing the force of falling water, which for thousands of years has been running to waste. Perhaps the most notable example of this is Niagara.

POSSIBILITIES OF POWER AT NIAGARA FALLS

The falls of the Niagara River were discovered by white men in 1678. For many years engineers realized that if

only a fraction of the roaring waters could be harnessed, Niagara Falls could be made to do a vast amount of work. The flow of water and the natural head available constitute a source of power of more than 6,000,000 horsepower. This is the theoretical power. Treaty limitations and practical considerations make the power that can be developed much less.

The continuous flow of more than 200,000 cubic feet of water per second for every day in the year, drops a total of 326 feet between Lake Erie and Lake Ontario. Within a distance of one mile there is available a total head of 220 feet, and within five miles, 314 feet. This remarkable combination of great uniform flow and high head found at Niagara is not duplicated anywhere else in the world.

Early power developments at Niagara

The production of electricity by water is usually referred to as "hydro-electric" (from "hydro," meaning "water") development.

As early as 1852 the building of a hydraulic canal was begun, extending from the head of the rapids above the American falls to the edge of the gorge, a mile below. In 1861, after various delays, the canal was finished.

The year 1880 marked the installation of the first hydro-electric unit at Niagara Falls in Prospect Park. It was used to light fountains in the park.

In 1886 the New York legislature granted a special charter to the Niagara Falls Power Company, and in three years its work was completed. Another American company to enter the field was the Hydraulic Power and Manufacturing Company.

Regulations to preserve beauty of Niagara Falls

In 1909 the United States and Great Britain agreed by treaty to limit the amount of water to be taken from the American side to 20,000 cubic feet per second; and the amount on the Canadian side to 36,000 cubic feet per second. The larger the body of water coming over the falls, however, the greater is the erosion, and the diversion of a larger amount of water for power coupled with suitable hydraulic works for distributing the remaining water over the falls would tend to preserve the surface beauty of the falls. It has, therefore, been suggested that a revision of the treaty may be made to permit the use of a greater quantity of water by both the United States and Canada for hydro-electric development.

Hydro-electric developments on the American side

During the World War emergency three large American companies were merged under the name of The Niagara Falls Power Company. The merged interests also controlled the Canadian Niagara Power Company on the Canadian side. These plants had a total capacity of 350,000 horsepower.

After the war, the U. S. Federal Power Commission approved plans whereby the Niagara Falls Power Company developed an additional 100,000 horsepower project. The total installed capacity on the American side in 1932 was 562,550 horsepower.

Hydro-electric developments on the Canadian side

We have already mentioned the Canadian Niagara Falls Power Company, the water for which is drawn from the level of the upper river through an intake canal. Its capacity is 121,000 horsepower.

The Ontario Power Company began operation in 1905. Its intake is above the falls near the Dufferin Islands. The present capacity of this plant is

WE CAN SEE AT A GLANCE IN THIS PICTURE HOW THE NIAGARA FALLS ARE HARNESSED

A great wall is built out into the river to divert part of the water to what is called the forebay. From here the water passes into the penstock, the huge pipe through which it falls 180 feet with terrific force, turning the turbines at the bottom. The turbines, in their turn, revolve the generator, which generates the electricity. The current is carried by wires to the distributing station. The wires which distribute the electricity generated by the turbines are carried to the cities and towns on high steel towers to light cities, drive cars, and work the machinery of great factories over an area of hundreds of square miles. The tower shown in this picture is over two hundred feet high. The wires to Toronto, 88 miles away, run over a private road 80 feet wide.

something more than 160,000 horsepower. In 1917 the Hydro-Electric Power Commission of Ontario acquired this plant and now operates it.

The plant of the Electrical Development Company is located above the falls about halfway between the headworks of the Ontario Power Company and those of the Canadian Power Company. In 1920 this plant was secured by the cities of the Niagara district and it is operated by the Hydro-Electric Power Commission. Its capacity is 125,000 horsepower.

Queenston-Chippawa Power Development

The newest and largest of the Canadian developments on the Niagara River is the Queenston-Chippawa Power Development of the Hydro-Electric Power Commission of Ontario, built to supply electrical energy to the people of that Province.

The two main features of this development are the Queenston-Chippawa canal and the Queenston power house. The canal carries the water of the upper Niagara river a distance of 12¾ miles to the power house which is situated near the village of Queenston on the lower Niagara River about twelve miles from Lake Ontario. Thus nearly the whole fall of the Niagara River—above the falls, at the falls and below them, actually 315 feet out of a total of 326 feet—is made use of. The generating stations situated at the falls make use of only about one-half of this total fall and thus the generators in the Queenston power house get about twice as much power out of a given quantity of water as do those in the older stations.

The Building of a Great Power Canal

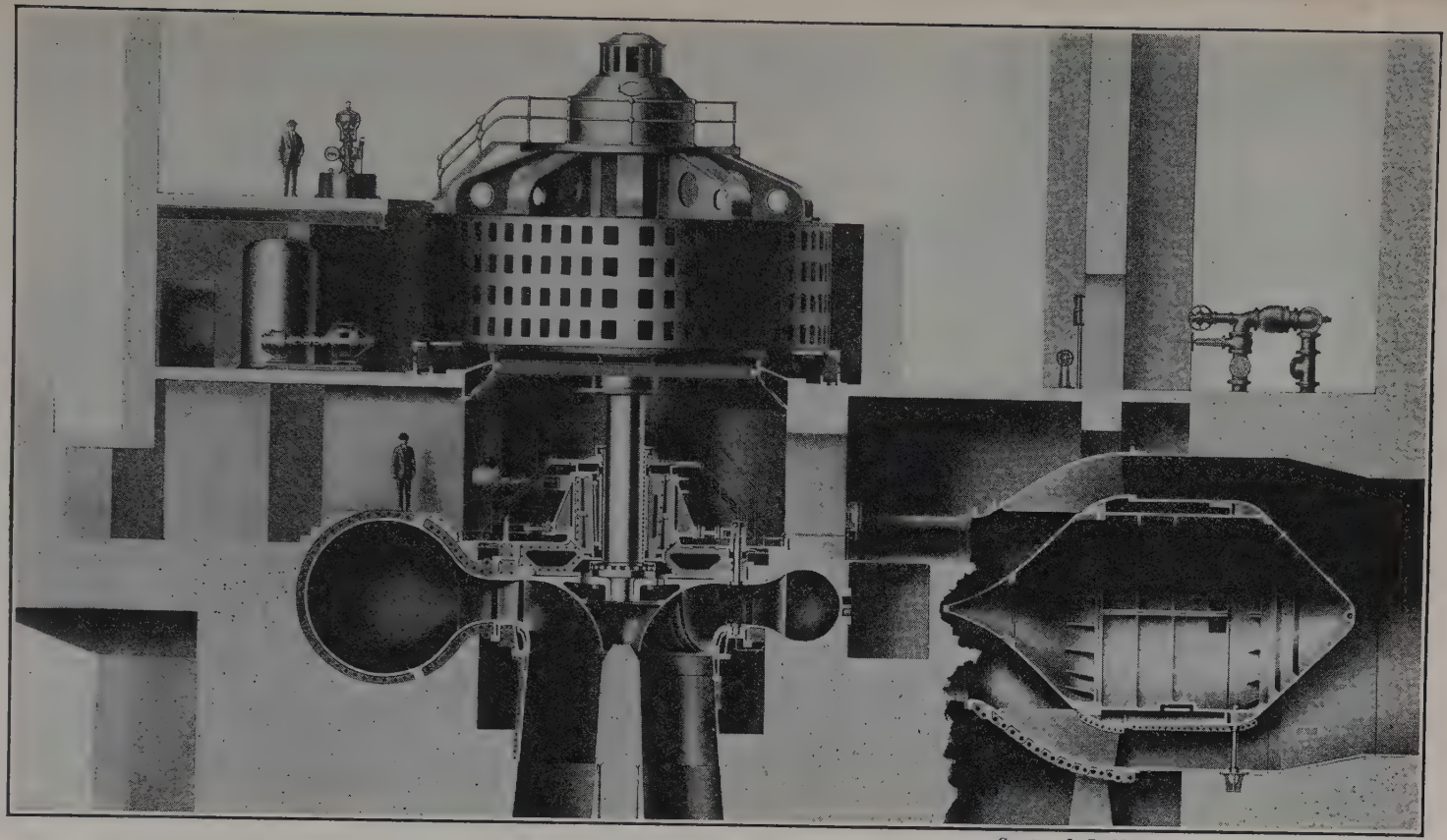
The Queenston-Chippawa power canal is one of the world's great engineering undertakings. Its construction meant the digging of 11,000,000 cubic yards of earth and 4,000,000 cubic yards of rock. Some idea of what these figures mean may be gained from the statement that this volume of material would be enough to cover a road twenty feet wide and nearly fifteen inches deep, stretching from New York to San Francisco, a distance of over 3,000 miles.

In the work of digging, huge electrically-driven shovels, the largest in the world and the first to be operated by electricity, were used. These shovels could dig out eight cubic yards of material at one stroke and put it on the canal bank at a level seventy-two feet above the base of the shovel. Naturally, much blasting was necessary in cutting through the rock and in one place no less than 1,100 holes were drilled, charged with dynamite, and fired all at the same time by electricity, thus, in one operation, breaking up about 25,000 cubic yards covering half an acre of ground and weighing about 50,000 tons. The canal has cut right across the routes of several important railway lines and highways and no less than thirteen bridges had to be built to close up the gaps so formed.

No Visible Wheels to Indicate Power

Stories are told of visitors to the falls who, after being impressed by the grandeur of the scene, ask, "Where are the wheels from which the power is obtained?" As a matter of fact there is nothing at the falls to indicate that man has in any way harnessed them for his benefit. But at points on the river, above the falls, there are wing dams and openings into which the water runs and is conveyed to turbines, sometimes laid deep down in the earth, which generate the power.

These turbines are from 170 to 300 feet lower than the surface level of the river above the falls. The water is supplied through canals and pipes.



Courtesy I. P. Morris Division, Baldwin-Southwark Corp.

GIGANTIC TURBINE HARNESSING THE POWER OF NIAGARA FALLS

Water from the river above Niagara Falls flows into the turbine through the valve shown at the right. It then passes from the snail-shaped turbine casing through adjustable gates to the runner which it turns, thus producing electricity from the generator located above. After leaving the runner the water passes into the river through the two tubes leading down from the center. The two men shown in the illustration indicate the huge size of the turbine.

Immense intake structure keeps ice out of canal

At the point where the water of the upper Niagara River flows into the Queenston-Chippawa power canal an immense intake structure of reinforced concrete has been made. This has been specially designed to prevent ice from entering the canal in the winter time. At the Queenston end the canal opens out into a large basin, called a "forebay," the water in which, when the necessary gates are opened, is allowed to flow down through great tubes, called penstocks, to the hydraulic turbines 300 feet below.

Huge hydraulic turbines

A turbine is composed of a number of vanes set spoke-wise round an axis, and enclosed in a cylinder in such a fashion that all water passing through the cylinder must push the vanes aside in its course, imparting to them, and therefore to their axis, a circular motion. Attached to the turbines are revolving shafts of steel which in turn drive the generators in the power houses and thus produce the electrical energy, or hydro-electric power.

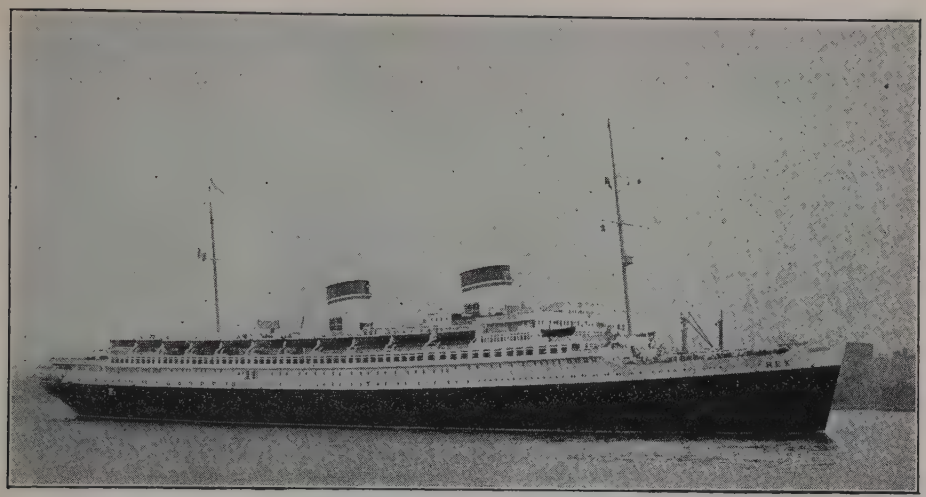
The penstocks, which are of steel, and have been embedded in concrete to keep them from rusting, are each sixteen feet in diameter and each supplies a single hydraulic turbine of about 55,000 to 60,000 horsepower capacity. There are now ten of these enormous machines installed. So far as present plans are concerned, the project was completed in 1930 and a total installed capacity of about 590,000 horsepower has been provided.

Each hydraulic turbine is connected directly to an electric generator operating at 12,000 volts and running at a speed of 187.5 revolutions per minute. Every generator has its own set of three transformers which "steps up" the voltage from 12,000 to 110,000 volts and feeds into the great transmission lines, supported on huge steel towers, carrying the electric current to all parts of southwestern Ontario.

The Hydro-Electric Power Commission of Ontario on behalf of the coöperating municipalities of the Province now owns and operates three of the four large power plants on the Canadian side of the Niagara river. The total output of these plants now exceeds 800,000 horsepower, a portion of which is exported from Canada to the United States.

The electrical energy generated at Niagara is taken by high-tension transmission lines to cities, towns, villages and rural communities. It lights the home and store of the humble citizen; it operates the street railways and elevators which carry him to and from his daily employment; it turns the wheels of the factories and is employed in numberless processes in industry; it relieves the modern housewife of much of the drudgery of housework and in a thousand ways enters into the daily life of the modern community.

Putting Niagara to work in this fashion has resulted in the rise of many busy manufacturing cities on both sides of the falls. Even in Buffalo, where coal is comparatively cheap, electric power from the falls is widely used. The street cars of Syracuse on the east and Windsor on the west—400 miles apart—are operated by Niagara power. Year by year the great electrical transmission lines extend farther and farther to supply town after town.



THE "REX" OF THE ITALIAN LINE

WATER NAVIGATION

DID the ancient Egyptians on the Nile with their many-oared boats ever dream of palatial day-line steamers carrying their thousands of passengers up and down the scenic Hudson? Did the sailors on the caravels that bore Columbus to the New World ever think of days ahead when ocean liners, such as the *Normandie* and the *Queen Mary*, would plow the waters of the Atlantic at a speed of more than thirty miles an hour carrying a population of thousands of passengers who could enjoy the comforts and conveniences of the finest hotels? The building of ships is one of the oldest enterprises of man and one that has in recent years made most notable progress.

PRIMITIVE WATER CRAFT

The Eskimo, with wonderful skill built his kayak from driftwood and skins. As shown in our picture he left a small opening and tied himself in so securely that he could roll over and over in the water without getting wet.

The Indian made his dugout from the trunk of a tree, cutting out his boat with the aid of fire and stone hatchets. A dugout would carry from ten to twelve people. The Indian also made the light birchbark canoe with which he skimmed the inland waters.

Our Colonial fathers made scows and ferryboats with which they crossed streams, often taking along their household goods and live stock. General Washington used scows and flatboats to take his army across the Delaware River on that eventful night when he surprised the Hessians at Trenton.

U. S. Bur. of Education Photo

ESKIMO KAYAK

The navigators of the kayak tie themselves in so securely that they can roll over and over in the water without getting wet.

EGYPTIANS, PHOENICIANS, GREEKS, ROMANS, NORSEMEN

Egyptians, Phoenicians, Greeks, Romans, Norsemen—these and many others with their galleys, triremes and other types of vessels propelled by oars and sails explored the seas and made many a thrilling and adventuresome voyage.

SHIPS WITH SAILS

More and more, however, men took to the exclusive use of sails. The advance of England to the position of leadership upon the high seas was made with sailing ships. In our own country the Yankee clipper ships of the middle nineteenth century were famous. With their great spread of square-rigged canvas they moved swiftly, or "clipped," through the water. The clippers were among the last of the types of sailing vessels to be developed.

Today in our country sailing ships are used mainly for coastwise and fishing purposes. Most common is the schooner, typically a two-masted vessel. It was first built at Gloucester, Massachusetts, about 1713, by Captain Andrew Robinson. It received its name from an incident that happened on the day the first vessel was launched. An onlooker exclaimed, "O, how she *scoons!*" and Captain Robinson replied, "A *scooner* let her be." (The name is from a Scandinavian word meaning to "skip" or "skim.")

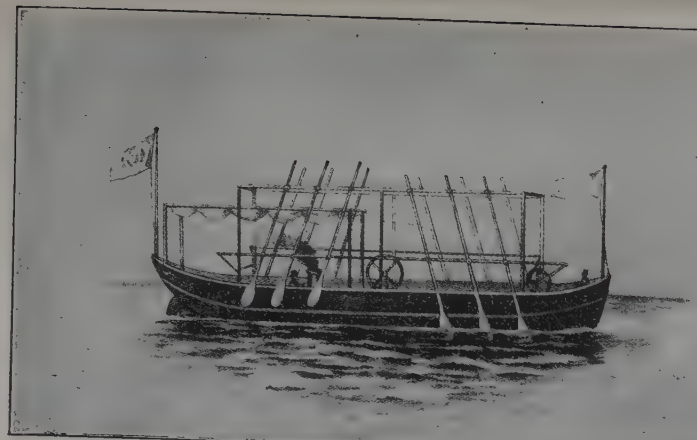
HOW JOHN FITCH BLAZED THE TRAIL FOR MODERN STEAMSHIP

John Fitch, a Connecticut watchmaker and a maker of guns during the Revolution, was captured by Indians in the wilds of the West. He escaped and settled in Pennsylvania. He was impressed with the need of navigating the rivers of inland America. He set about devising a steamboat, and in 1785 produced a model which won the favor of a professor at the University of Pennsylvania. The model had buckets attached to the side, but Fitch soon replaced them with oars. Both models worked. He built a steam ferryboat which operated on the Delaware River between Philadelphia and Burlington, a distance of twenty miles, during the summer of 1790. Although James Rumsey had exhibited a steamboat on the Potomac three years before this time, Fitch's was the first successful steamboat. A few years later Fitch constructed and demonstrated a steamboat with a screw propeller at New York City.

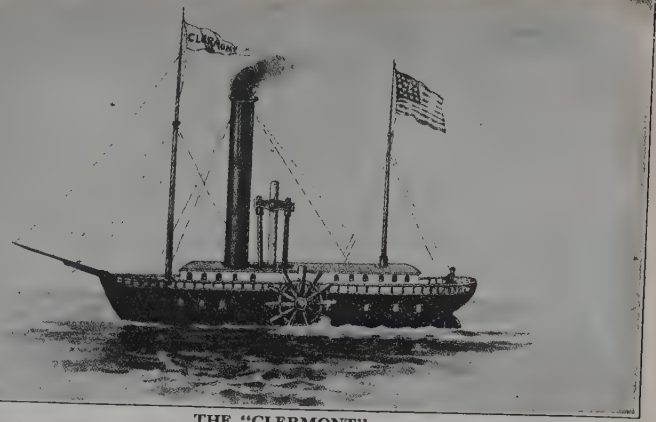
Fitch had unlimited confidence in his inventions, but he failed to interest others. Even the great Franklin, himself a distinguished scientist, had only pity for the struggling inventor and would not help him. Fitch tried to get the state legislature to help with money but to no avail. Failing to secure enough capital to build a boat large enough to prove his ideas, he went to France and again failed to interest capital. He handed his plans to the American consul in Paris and in this way they came to be examined by Robert Fulton, another American, who was then working on the problems of steam navigation. Thoroughly disheartened Fitch returned to his native country and retired to Kentucky where, with hope entirely killed, he ended his life with his own hand in 1798.

SAMUEL MOREY AND HIS STEAMBOATS

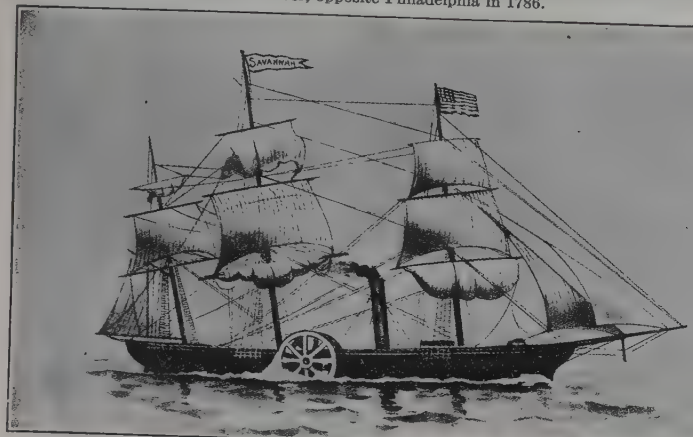
Our story would be incomplete without mention of the work of a New England inventor, Samuel Morey. For years he worked on the problem of steam navigation and in 1793 Morey's steamboat, fitted with a paddle wheel which was put first at the prow and later at the stern, made a successful trip on the Connecticut River between Orford, New



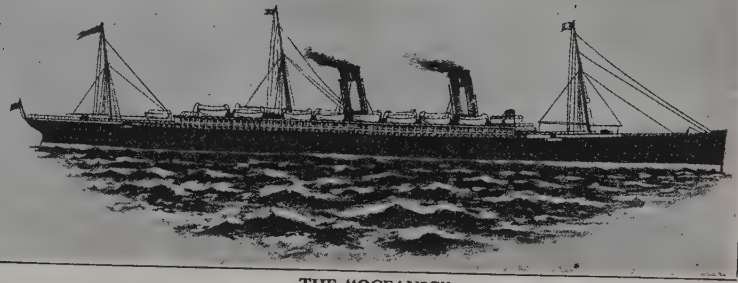
"JOHN FITCH"
This is positively the first steamboat ever built. The above illustration shows the boat as it appeared on the Delaware River, opposite Philadelphia in 1786.



THE "CLERMONT"
Made the trip from New York City to Albany, September, 1807. The "John Fitch" was built and operated on the Delaware River 21 years before the Clermont was completed.



STEAMSHIP "SAVANNAH"
The first steamship to cross the Atlantic Ocean. Sailed from Savannah, Georgia, on May 20th, 1819; arrived at Liverpool, England, June 11th, 1819.



THE "OCEANIC"
Completed in 1901 and called the "Queen of the Ocean." It was 704 feet in length. This great ship was blown up during the World War.

Hampshire and Fairlee, Vermont, attaining a speed of about four miles an hour. Morey went to New York and New Jersey and made other steamboats. Success seemed just within his grasp, but misfortunes overtook him and the honors that might have been his went to Fulton instead. Morey engaged in the logging business and the world heard no more of him.

THE CONTRIBUTION OF JOHN STEVENS AND OF HIS SON, ROBERT, TO STEAM NAVIGATION

The Stevens, father and son, were among the best engineers of their time. Years before Fulton ran his steamboat, John Stevens was running one on the Hudson. In 1804 he built a screw-propelled steamboat, the first of its kind. Robert helped his father in this earlier work and later developed the *New Philadelphia*, the steamboat that initiated the first day line to Albany. To Robert Stevens is due the present-day form of ferryboat and river steamboat. His inventions and their improvements would fill a long column.

THE WORK OF ROBERT FULTON AND ROBERT LIVINGSTON

Fitch had lost his rights to navigation on the Hudson because he failed to make a speed of four miles an hour. The rights were taken over by the wealthy Robert R. Livingston, of New York, who then tried, but failed in the attempt, to build a steamboat that would attain the necessary speed. Livingston went as Minister to France where he met Robert Fulton, who since the age of thirteen had been building boats of various kinds. Fulton was an eager student of the results obtained by English and French engineers in their work on steam navigation problems.

Returning to the United States, Fulton began the construction of a steamboat which he called the *Clermont*, after Livingston's country estate on the Hudson. The people who watched the growth of the new craft had another name for it—"Fulton's Folly." The doubters and scoffers were silenced, however, when, in 1807, the *Clermont*, made the run from New York City to Albany in thirty-two hours—150 miles at the rate of almost five miles an hour. This was safely over the four-mile requirement and gave Fulton the right to navigate the waters of the State of New York. (See more complete story of Fulton in Vol. VI.)

And so steam navigation became practical. Fulton never claimed that he was the inventor of the steamboat, but only that he was able to build a commercially successful vessel propelled by the power of steam. Working with Livingston, Fulton went ahead to make many improvements on the *Clermont*, including machinery for more efficient operation of the boat and devices for the greater comfort of the passengers.

THE FIRST STEAMSHIP TO CROSS THE ATLANTIC

The next step was to go across the ocean, and the first steam vessel to do this was the *Savannah*. It is an interesting fact that the engines for this ship were built in a little factory in Morristown, New Jersey, where Morse worked out his invention of the telegraph. The ship was mainly owned in the city of Savannah, from which she took her name. The steam engines were used only part of the time, for when the weather was rough the paddle wheels were removed and sails used. But the *Savannah* showed the way to bridge the Atlantic, reaching Liverpool on her trip from New York City in the space of twenty-seven days.

Mississippi river steamboats

Nicholas J. Roosevelt, of New York, was a pioneer in placing steamboats on the Mississippi. As a boy, Nicholas had propelled a toy boat with paddle wheels made to turn by the use of whalebone and hickory springs. Backed by the Livingston - Fulton group, Roosevelt went to work to build a steamboat to navigate the turbulent waters of the Mississippi and take the place of the unwieldy flatboats and rafts which could go only downstream. The doubters and skeptics were present and as the building went on said, "Just wait till the old teakettle tries to go upstream." But Roosevelt's boat went, and she kept on going.

The era of the river steamboat was ushered in. Much of the development of the rich Mississippi Valley is due to the steamboats which grew larger and larger and carried men and goods up and down this vast territory.

Many are the tales of river steamboat days. There was a young man from Hannibal, Missouri, who became a river pilot and later a famous writer under the pen name of Mark Twain. He received this name from the cry of the man who cast the lead making soundings. The chant of "mark twain, mark twain" meant that the depth of the channel there was two fathoms.

But the coming of the railroad spelled the doom of the steamboat. Carrying so many laborers, or deck hands, and with long waits and periods of inactivity, the boat could not compete with the railroad. However with cheaply operated barges and oil burners there is at present a revival in river transportation which may increase.

Steam navigation on the great lakes and canals

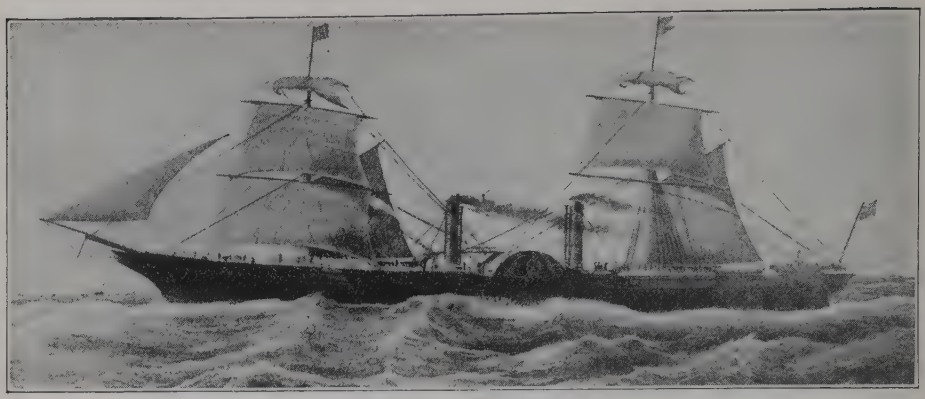
With the aid of canals the Great Lakes have become very important in transportation, the tonnage carried rivaling that carried in ocean steamers. Palatial excursion and regular steamers, which compare favorably in their equipment with ocean liners, ply on the waters of the Great Lakes.

The race between the great western and the sirius

Sir Isambard Kingdom Brunel, eminent English engineer, seeking new fields to conquer, designed and built the steamship *Great Western*, a paddle-wheel vessel 236 feet long, for the purpose of crossing the Atlantic. A rival company, hearing of this attempt, chartered the newly completed *Sirius*, 178 feet long, and entered the race. The *Sirius* got away three days ahead and beat the *Great Western* to New York by a few hours. The *Great Western* arrived the next day, making the crossing in fifteen days. New York City staged a great celebration, decking the two ships in bunting and thronging the decks with admiring crowds to see these new wonders of the sea.

From the great western to the normandie

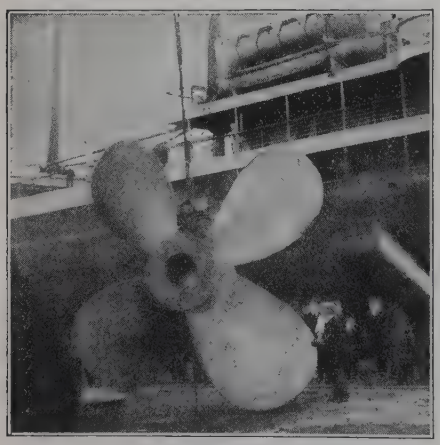
The *Great Western* attained a speed of eight or nine knots (a knot is 6080.2 feet, a mile and one-seventh) an hour. The *Normandie* has made thirty-two knots and some smaller vessels reach forty knots. Great improvement in speed has come with the use of the screw propeller. The compound engine of Hornblower was first introduced in a vessel in 1829. The steam turbine of Parsons was first used in a boat in the *Turbinia*, a steamboat, in 1897. The advance of the Diesel engine has been rapid, bringing a great economy in consumption of fuel oil and in fuel storage space. The Diesel engine has no boilers or furnaces. It burns oil in its cylinders just as gasoline is burned in an automobile.



A CUNARDER OF OLDER DAYS
The *Persia*, a Cunard Royal Mail paddle steamship.

How Samuel Cunard planned a network of ships for the Atlantic

Samuel Cunard, a prominent Canadian merchant who lived in Halifax, conceived the idea of a network of steamship lines to cover the Atlantic



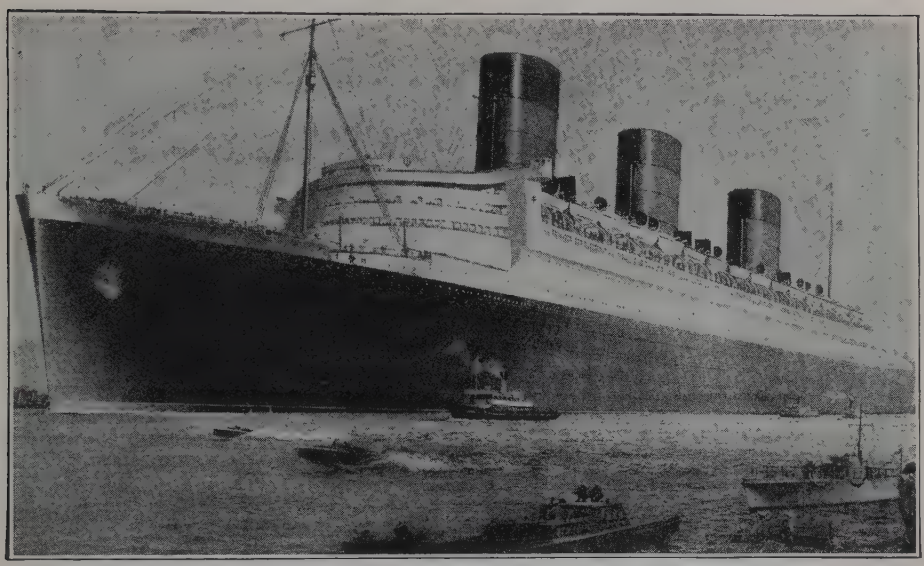
SCREW PROPELLER
This huge screw and three others like it drive the *Majestic* through the water at a service speed of more than twenty-five knots (nearly thirty miles) an hour.

in the way that railway systems cover the land. He planned that the ships should run on regular schedules. His dream was communicated to others and with Burns and MacIver he formed a company in England which established, in 1859, the first regular transatlantic service, and secured the contract of carrying the mails. From the first fleet of four wooden ships, now displaced by those of steel, has come the Cunard White Star line.

Building a modern ocean liner

It is no exaggeration to say that there is nothing that man fashions today that calls for more skill, ingenuity, forethought, and judgment than the designing and building of a large ship. Be it a great liner that will carry thousands of passengers across the ocean at express speed, in spacious and comfortable salons, or a mighty battleship with an array of formidable guns, all the knowledge, craft, and cunning that the modern shipwright can display will be needed in the evolving of the vessel. From the time the ship is planned in the drafting room until she takes the water at her launching, the brains of learned mathematicians, assisted by the might of complicated and wonderful machinery, and the labor of an army of skilled workmen, are constantly required.

For this reason there is no place so bewildering and fascinating as a modern shipbuilding yard. No place gives a better idea of the progress that has been made in engineering. First there are the building berths. These berths



THE CUNARD WHITE STAR'S "QUEEN MARY"
Christened by Britain's Queen Mary in 1934 and entered transatlantic service in 1936.

THE "NORMANDIE," PRIDE OF THE FRENCH LINE
On her first trip across the Atlantic the "Normandie" established a new speed record.

A WONDERFUL SWIMMING POOL

This swimming pool is in the "Berengaria." It was copied from Pompeiian designs and is one of the finest in any ship.

may be inclosed by neat, steel lattice-work walls, or be entirely open. Here the hulls are built up, piece by piece, amid an ever-growing forest of scaffolding. From the overhead girders, that span the site, run cranes that pick up heavy steel plates and beams, weighing many tons, as if they were mere toys, and lift them into the desired position.

Indeed, all the marvels of machinery are here, driven by steam, electricity, compressed air and water. There are the great presses that bend the steel plates into the desired shape and form; machines that punch holes by the score in them, for the rivets, as easily as you can stick a knife through a piece of paper, while others bite large holes in the hard steel, or reduce the size of the plates by literally slicing off a piece, as deftly and as easily as you could carve a slice off a loaf of bread. Above all, there is the wonderful activity, the constant clang of the riveters' hammers, the snorting of many engines, the glow of furnaces, the rattle of heavy chains, the shouts of the foremen, the toiling mass of humanity, all creating an ordered chaos the like of which can be found nowhere but at those busy yards by the river-banks where great ships are born.

Naturally, the men in the yard cannot start upon the ship till it has been

FROM THE CARAVEL OF COLUMBUS TO THE MODERN OCEAN LINER

planned. This is the work of the draughtsmen, and at all the big yards there is what is termed a drawing or mold loft, an immense room, so large that designs can be made to the actual scale of the vessel. This is necessary if the ship is larger than any existing vessel or of a different type from what the builder has turned out before. In that case the draughtsman, taking the floor of his room as an immense blackboard, chalks out in mighty lines all the girders, frames, beams and plates. Everything, down to the rivets and rivet-holes, is drawn full size. From these great drawings the working plans are prepared. Then in an immense floor of pine-wood, called the "scrieve-board," the body plan of the ship is cut, from which wooden models are made of her outlines. From these plans the steel of which the ship is to be built is ordered, as well as all other necessary material.

Now commences the erection of the hull, which is, in essence, a steel box of curious design. Down the center of the floor are placed portable balks of wood forming piles from 4 to 5 feet high, and known as keel blocks. It is upon these that the keel of the ship is laid. It is a girder of the strongest kind, as it needs to be, seeing that at one moment it may be in the trough of a wave, deeply immersed fore and aft only, and the next riding on its crest with bow and stern almost out of the water. It has, too, to withstand the terrific blows of ocean billows, which tend to bend it sideways.

The strength of the ship lies in this keel and the center girder running from one end of the ship to the other. On either side are other girders, running parallel to it, and from these, at various intervals on both sides, spring the ribs or frames, which curve upwards, and to which the plates that form the sides of the ship are fastened. The ribs are held in place by horizontal rafters or beams that carry the decks.

In the case of the modern liner it is now built with an inner skin. That is to say, there are virtually two hulls, one within the other, carried well up above the water-line. The vessel is also provided with a double bottom, while, as an additional precaution, in case of injury by collision that part of the vessel below the water-line is divided into water-tight compartments.

The Cunard White Star liner *Berengaria* is almost one-fifth of a mile long. Her beam of 98 feet is approximately the width of a city street.

She carries five anchors, the main one weighing 12 tons, the combined weight of the five anchors and chains being 217 tons. The cargo of many a small steamer is not much larger.

The vessel has a height of 96 feet, her great sides being built upon 327 steel ribs on either side, each weighing over a ton. The weight of the steel plates, angles, profiles, and the like totals 260 tons. More than 2,000,000 steel rivets were used in her construction, each weighing 11 lbs. Because of her great size her decks are particularly imposing. Two of her three broad decks are partially enclosed. The promenades vary in width from 16 to 23 feet, while the circuit of the deck is equal to a walk of five ordinary city blocks.

The North German Lloyd liner *Bremen* on her maiden trip in July, 1929, set a new transatlantic record of 4 days, 17 hours and 42 minutes, thus beating the time of the *Mauretania* by almost 9 hours. The *Mauretania* came back in August of the same year with a record only seven minutes longer than the *Bremen's*. Later the *Bremen* lowered the transatlantic record to 4 days, 14 hours and 30 minutes. The Italian liner, *Rex*, crossed in 4 days, 13 hours and 58 minutes (from Gi-

MIGHTY CARRIERS ON THE SEAS

THE "BREMEN," FAST GERMAN LLOYD LINER, WHICH IN 1929 LOWERED THE TRANS-ATLANTIC RECORD BY ALMOST NINE HOURS

"BERENGARIA" ARRIVING IN NEW YORK HARBOR, SHOWING THE OUTLINES OF ITS IMMENSE HULK AGAINST THE CITY'S SKYSCRAPERS

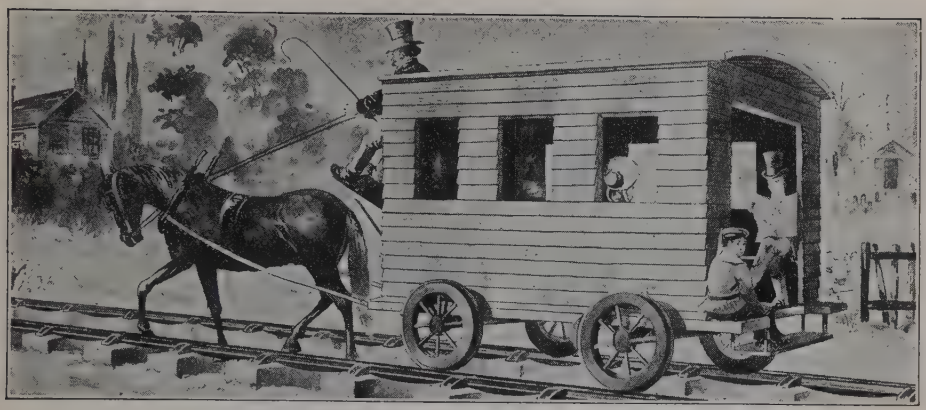
braltar). The *Normandie* on her maiden trip in 1935 crossed in 4 days, 3 hours and 5 minutes, averaging 29.68 knots per hour. The *Bremen* is a masterpiece for convenience and comfort and is equipped with every known safety device. She is a 51,655 ton vessel, 938 feet long and 98 feet wide, an oil burner driven by steam turbines. The squat funnels are shaped like the cross section of a raindrop. The smoke is carried up the sides of the liner, thus making possible spacious public rooms. One of the funnels is large enough to slip over a four-story apartment building with room to spare.

The smoking room of the *Berengaria* is a beautiful saloon of the Tudor period. It has a large open fireplace, the red brickwork over which realistically reproduces that of the sixteenth century. The bricks in question came from a Buckinghamshire cottage of the Tudor period, which was demolished for the purpose. The main lounge is 72 feet long, 58 feet wide, and 18 feet high; the floor is of parquet, which is covered with a carpet; the walls are decorated with costly old Gobelin tapestry, and have bow windows 10 feet high on either side. It has been constructed with no pillars visibly supporting it. The scheme of decoration is Louis XV. Other unique features of the ship are the two self-contained suites or apartments, comprising drawing-room and veranda, with large windows opening out over the sea, dining room, two bedrooms, two bathrooms and two trunk rooms.

The Roman bath on the *Berengaria*, with its decorative Pompeian pillars and ornamental cascades of running water, is a masterpiece. The swimming pool has been built after the designs of the ancient Romans. The total length of the bath is 65 feet, the width 41 feet, and the greatest depth of water 7 feet. There are also electric, Turkish, and steam-baths, massage apparatus, and hair-dressing saloons with the most modern equipments, as well as a splendid gymnasium containing everything to satisfy the most exacting requirements. Other features include a sweet shop and a photographer's dark room.

On June 3, 1935, the French liner, *Normandie*, came into New York harbor completing her maiden trip across the Atlantic and making a new record for the crossing. This gigantic ship has a gross tonnage of 79,280 and is 1029 feet in length. Standing on end this super-liner would tower to within seventeen feet of the top of the Chrysler tower and would surmount the 70-story R.C.A. Building in Radio City by 175 feet. The ship's crew numbers 1320 and she can carry 2170 passengers. Her four great electrically driven propellers weigh 23 tons each and the anchors weigh 17 tons apiece.

The Cunard White Star liner *Queen Mary* entered transatlantic service in May, 1936. The ship had been christened on September 26, 1934, by Her Majesty, Queen Mary, with King George standing by. The *Queen Mary* is 1019.5 feet long and her gross tonnage is 80,773. With engines capable of approximately 200,000 horsepower the ship makes the Atlantic crossing in four days. The *Queen Mary* captured the speed laurels in late August, 1936, by crossing the Atlantic eastbound in 3 days, 23 hours and 57 minutes. The average speed on this crossing was 30.63 knots. The cabin class lounge of the *Queen Mary* is so large that nine double-deck busses placed abreast with three railroad engines placed on their roofs could easily be accommodated in the room. A restaurant (18,720 square feet) is by far the largest room afloat. The *Queen Mary* accommodates 2,000 passengers.



BALTIMORE AND OHIO RAILROAD PASSENGER CAR—1830

RAILROADS

THE earliest railroads were the artificial grooves or ruts cut to receive the wheels of vehicles in the surface of certain ancient roadways. The Egyptians, Greeks and Romans were familiar with this method of providing a smooth, hard track for wheels, and it is said that the device was known even to the prehistoric people of central Europe. Hero of Alexandria, the most remarkable inventor of antiquity, constructed mechanical toys, or automata, that ran on wheels over wooden rails; thus anticipating the form of the modern railway.

Parallel beams of wood over which loaded carts could be pushed or pulled were used by English and German miners as early as the sixteenth century of our era. These "tramways," as they were called, underwent many improvements, especially in the English coal-mining district around Newcastle-on-Tyne. The wooden beams, or rails, were made in sections about six feet long, and were fastened down by wooden pins driven through them to crossbars, called "sleepers." In time it became the custom to cover them with a thin plating of iron, in order that they might wear longer. After the middle of the eighteenth century some rails were made entirely of iron, with an upright ridge, or flange, at the inner side to keep the wheels of the carts on the track.

THE FIRST STEAM LOCOMOTIVE

Thus the highway for the steam locomotive was prepared long before the locomotive itself appeared. When it did appear, it ran first on an ordinary road, and not on rails. Richard Trevithick built a steam "road locomotive"—an ancestor of the automobile—which carried eight passengers over an English highway in 1801. Three years later he built a locomotive to haul cars over rails. In this pioneer engine he introduced the plan that has been followed ever since of exhausting the steam from the cylinders into the smokestack, thus increasing the draft through the furnace.

STEVENSON AND THE DEVELOPMENT OF THE STEAM RAILROAD

During the first quarter of the nineteenth century inventors on both

sides of the Atlantic were working on ideas for steam railroads. The man who did most to make them a success was an Englishman, George Stephenson. An epoch-making event in railway history was the opening of the Stockton & Darlington line, thirty-eight miles long, on September 27, 1825. The original plan had been to use horses on this line, but Stephenson, its engineer, who had built a successful locomotive ten years earlier, persuaded the management to try steam instead. On the opening day a train of thirty-four vehicles was drawn by a single engine, driven by Stephenson, with a horseman riding ahead as signalman. This train attained a speed of fifteen miles an hour. In 1829 came the famous competition between the locomotives of rival inventors on the new Liverpool & Manchester Railway, in which the prize of £500 was won by Stephenson's "Rocket." This locomotive drew a train weighing thirteen tons at a speed of nearly fourteen miles an hour. Thus began the age of rapid transit. The Liverpool & Manchester Railway proved so successful financially that railroad building soon became a veritable mania in England.

Early American steam locomotives

News of these events aroused great interest in America, where already several crude tramways had been built for horse-drawn vehicles, and even some experimental steam locomotives had been constructed. A tramway for transporting bricks is said to have been used near Boston before 1800, and one built in 1826 to carry granite for the Bunker Hill Monument from the quarries at Quincy to a wharf four miles distant was so famous that visitors came from far and near to see it.

The first spadeful of earth for the first railroad in America was turned in Maryland by the venerable Charles Carroll of Carrollton, who made this statement at the time: "I consider this one of the most important acts of my life, in fact, second only to the signing of the Declaration of Independence." This event took place in 1828. At that time Carroll was the sole survivor of the signers of the Declaration.

In 1827 the Baltimore & Ohio Railroad was chartered, and by 1830 "brigades" of cars (as the trains were called), drawn by teams of horses, were running between Baltimore and Ellicott's Mills, a distance of thirteen miles. (See P. 219, Vol. IV.)

The Delaware & Hudson Canal Company sent one of its engineers, Horatio Allen, to England in 1828 to investigate the railroad situation. The result was that four locomotives were ordered of English builders and the company constructed a line of railroad seventeen miles long for carrying coal over the mountains between Carbondale and Honesdale, Pennsylvania. The tracks were of wood, with a half inch plating of iron. Only one of the English locomotives, the "Stourbridge Lion," was ever used on this road. The trial trip was made on August 9, 1829, with Allen himself at the throttle and no passengers. The engine was more than twice as heavy as had been expected, and its use on the flimsy rails was a perilous undertaking. The journey was safely accomplished, and, although the locomotive was dismantled soon afterward, the object lesson gave a great impetus to the development of railroads in this country.

Peter Cooper and his "Tom Thumb" engine

The building of locomotives in America for regular use on railroads began in 1830. In that year Peter

Cooper, of New York, bought a stationary steam engine, with a vertical boiler and a single cylinder, rigged it on a small car, and thus improvised the "Tom Thumb." This was the first locomotive employed on the Baltimore & Ohio, which had become dissatisfied with horse power and had been experimenting with a car that carried a sail for utilizing the power of the wind.

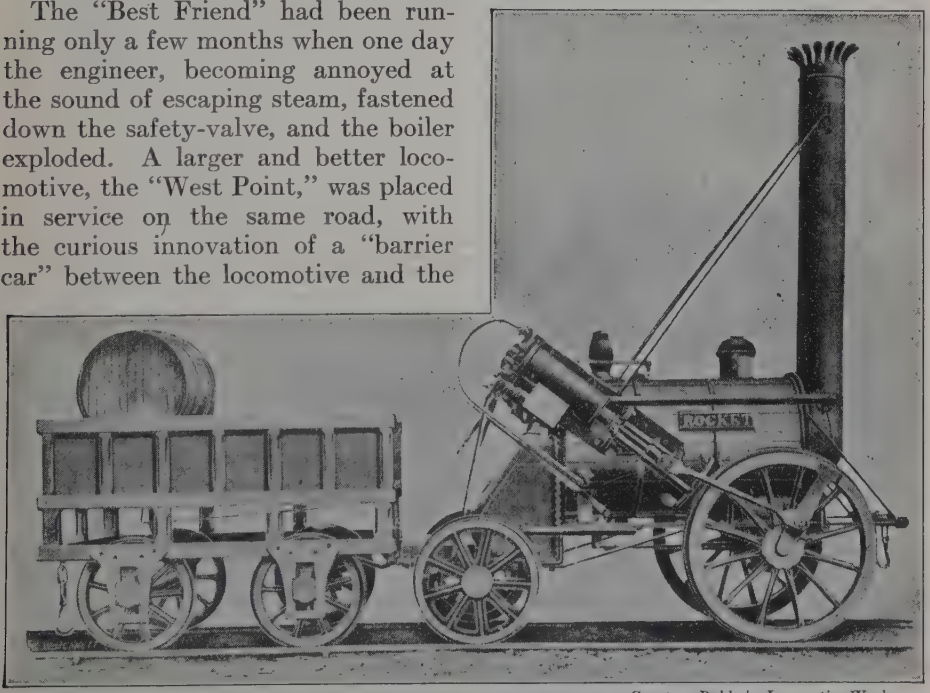
THE "BEST FRIEND" AND THE "WEST POINT"

A less primitive locomotive, the "Best Friend," was built in 1830 at the West Point Foundry, in New York City, for the South Carolina Railroad, and inaugurated a regular passenger service on that road in 1831. It could haul four or five cars with forty or fifty passengers at a speed of from fifteen to twenty-five miles an hour.

The "Best Friend" had been running only a few months when one day the engineer, becoming annoyed at the sound of escaping steam, fastened down the safety-valve, and the boiler exploded. A larger and better locomotive, the "West Point," was placed in service on the same road, with the curious innovation of a "barrier car" between the locomotive and the passenger coaches. This was a car loaded with bales of cotton, widely advertised as a good protection to the passengers "when the locomotive exploded."

A FAMOUS LOCOMOTIVE WHICH WEIGHED LESS THAN A PAIR OF MODERN DRIVING WHEELS

The most famous of early American locomotives, the "De Witt Clinton," made its first run from Albany to Schenectady on the Mohawk & Hudson Railroad (now part of the New York Central system) on August 9, 1831. A full-sized model of this locomotive with its train of passenger cars, resembling stagecoaches, was shown at the Chicago Exposition in 1893, and in 1921 it was run under its own steam on various stretches of track throughout the country. The subsequent growth of locomotives is



Courtesy Baldwin Locomotive Works

STEPHENSON'S LOCOMOTIVE

George Stephenson's locomotive, the "Rocket," (1829). From his original model now in the National Museum at Washington.

well indicated by the fact that the "De Witt Clinton" with its tender weighed less than a pair of driving wheels on one of the monsters that pull modern passenger trains.

Progress in locomotive building

The early locomotives were built in a great variety of shapes. Some had vertical boilers, and in some there were overhead walking beams from which connecting rods ran to the driving wheels. When the "John Bull," imported from England in 1831, was reconstructed in this country to adapt it to the sharp curves of American railroads, it acquired a faint resemblance to the locomotives of today. This engine, with its pair of small wheels placed far forward and its long pilot, or cowcatcher, may now be seen in the National Museum at Washington. American builders made so much progress during the next decade that in 1840 they began exporting locomotives to England and elsewhere in Europe.

The heavier a locomotive, the better its grip on the rails and the greater its pulling power. In 1863 the Philadelphia & Reading built a pusher engine for coal trains having the unprecedented weight of fifty tons. Today coal is hauled over the Virginian Railway by enormous engines weighing 450 tons. The successive improvements in locomotive design, far too numerous to mention here, include the compounding of cylinders; the use of super-heaters, which raise the temperature of the steam several hundred degrees and save twenty-five per cent in fuel; and the introduction of the mechanical stoker, by which coal is fed from the tender into the fire box, saving the heavy labor of shoveling. Once all American locomotives burned wood. Now many burn oil, and a promising novelty is the use of finely pulverized coal, which is blown into the fire-box and burns in much the same way as gas.

Courtesy Pennsylvania Railroad System

"JOHN BULL" LOCOMOTIVE AND PIONEER TRAIN

An English-built locomotive, extensively remodeled in the United States. It was the first locomotive to have a pilot (cowcatcher), a headlight and a bell.

Electric locomotives

In the year 1895 the Baltimore & Ohio Railroad began using electric locomotives to haul trains through the Baltimore tunnel, in order to eliminate objectionable smoke and gases. This and other similar innovations at home and abroad led to the popular expectation that within a few years the use of steam would become obsolete on railroads, but up to the present time less than one per cent of the total railway mileage of the world has been electrified. Electricity has replaced steam in many long tunnels, in the yards of big city terminals, and on a few long stretches of railroad elsewhere, especially in regions where electricity is cheaply generated from water power. In

Courtesy Denver & Rio Grande Western R. R.

LARGE MODERN LOCOMOTIVE

The total weight of this huge passenger locomotive, with its tender, loaded, is 644,600 pounds, or more than 322 tons. It burns five and one-half tons of coal an hour, when running at full capacity.

general, however, the enormous cost of installing electrical equipment has prohibited its adoption. The progress of invention may lead to some device greatly superior to both the steam locomotive and the electric locomotive of today, and the railroads are disposed to await such developments. Steam locomotives driven by turbine engines have recently appeared in Europe. In this country as well as abroad, electric locomotives that generate their own electricity by means of a Diesel oil engine are now in use. Motor cars driven by gasoline engines are used for local passenger service on several railroads.

Some Interesting Developments in Railway Operation

The progress of locomotives has been paralleled by equally striking developments in the other factors of railway operation. Cast iron rails were first replaced by rails of wrought iron, and then, with the introduction of the Bessemer and open-hearth steel-making processes, by much stronger and cheaper rails of steel. No other feature of the railroad, except steam power itself, has contributed so much to its success as the steel rail.

Another revolutionary improvement in railroading was the air brake, invented by George Westinghouse and introduced in 1869. This device for stopping a train quickly not only lessens the danger of collisions but also, by shortening the process of slowing down on approaching stations, enables trains to maintain a higher speed than would otherwise be possible. Each car on a train carries a reservoir which is kept supplied with compressed air from the locomotive. All the reservoirs are connected with a pipe running the length of the train. When air is released from this pipe by the engineer, a mechanism is brought

OIL-ELECTRIC LOCOMOTIVE *Courtesy Great Northern R. R.*

This modern locomotive, weighing 216,600 pounds, eliminates objectionable smoke and gases.

into play that causes the compressed air in the reservoirs to set all the brakes at the same time.

Railroad signals

Two kinds of visual signals are used on railroads to advise the locomotive engineer whether he may proceed with safety—those which protect switches, junctions and crossings, and those which preserve a safe interval between trains running on the same track. In both cases the commonest form of day signal is the moving arm of a semaphore, while colored lights are used by night.

Signals of the first class are generally connected with ingenious "interlocking" machines installed in signal towers, and the same machines also operate neighboring switches. These machines are so constructed that a switch can never be set or a signal displayed that will bring two trains into collision. The interlocking machines used at big terminal stations for controlling train movements in the yard are connected electrically with the signals and switches, the movements of which are effected by either electricity or compressed air. They are the most wonderful of all mechanical devices used on railroads, and of foolproof devices used anywhere.

Signals of the second class, which maintain a safe distance between trains, are called "block signals." The road is divided into "blocks" of various lengths, the minimum length being that within which the brakes will stop the train. No two trains are allowed in the same block at the same time. A "stop" signal is used to show that there is a train in the next block ahead, while a "cautionary" signal means that the second block ahead is occupied. On most important lines these signals are set electrically by the movements of the trains themselves. A newer device is the "automatic train-stop," which sets the brakes on a train without the intervention of the engineer when there is a danger signal displayed ahead.

Development of the automatic coupler

The methods by which cars are "coupled," or joined together, vary in different countries. In the United States the "link-and-pin" coupler became universal many years ago. When two cars came together a link on one had to be guided by hand into a slot on the other, and a pin pushed into place. This process was so dangerous and caused so many accidents that inventors set their wits to work to devise an automatic coupler. Fully 4,000 different contrivances were patented before the coupler invented by E. H. Janney was adopted as the standard. Automatic couplers are now required by law in this country, though hand coupling still prevails abroad. Automatic couplers are locked together by the impact of the cars and are uncoupled by a hand-lever placed in a safe location.

Passenger cars

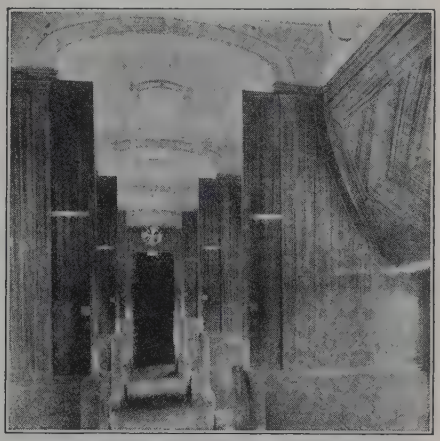
The earliest railway passenger cars differed little from old-fashioned stagecoaches. Gentlemen who preferred the privacy of their own carriages, in which they had been accustomed to travel before the advent of the railway, could have these vehicles placed on flat freight cars and thus transported. Combinations of two or more stagecoach bodies produced the compartment car, which still prevails in Europe, though on European express trains there are now corridors running the length of each car, on one side, in addition to the compartments. The American style of passenger coach, without compartments, originated on the Baltimore & Ohio Railroad in the early 'thirties.

Nearly all the comforts and conveniences of railway travel have come since 1840, when passenger cars had no springs, hardly any ventilation, and no better means of illumination than candles. Sleeping cars arrived in 1858 (there were some crude "bunk cars" of earlier date) and dining cars ten years later; both of these blessings being due to the genius of George M. Pullman. The use of "diners" necessitated passage from car to car and thus hastened the coming of the vestibule, introduced by a Pullman employee, H. H. Sessions, in 1887. The all-steel passenger car, a product of the twentieth century, has contributed notably to the safety of travel. The de luxe passenger train of today, electric-lighted and steam-heated, with electric fans, chair cars, club car, observation car, barber shop, bathrooms, searchlights to illuminate scenic beauty along the route, and radio to cap the climax of modernity, is a luxurious hotel on wheels. Except that our sleeping cars are still far from ideal, the limit of comfort seems to have been reached in American railway travel, but much remains to be done to insure perfect safety.

Courtesy The Pullman Company

ORIGINAL PULLMAN SLEEPER

Interior of the first Pullman sleeping car, made in 1859 from an old passenger coach.



MODERN PULLMAN SLEEPER

The development of the American sleeping car is shown in this picture.

Courtesy N. Y. Central R. R.

THE CAR THAT COMES TO PIECES

The container car here illustrated consists of several box-like containers fitted to a specially designed flat car. The boxes can be lifted separately from the car by a crane, to be loaded on motor trucks.

Courtesy Fairmont Railway Motors, Inc.

HOW THE RAILROAD SECTION GANGS TRAVEL

Old style and new. At the right the once universal hand car; on the left the motor car which has largely replaced it.

Freight cars

Freight cars are about forty times as numerous as passenger, express and mail cars combined, and the transport of freight is by far the most lucrative business of the railroad. Several distinct types of car have been evolved for different kinds of freight service. The box car, the gondola (an open-top car, with high or low sides) and the flat car are the three commonest shapes. Tank cars transport oil and other liquids, and stock cars carry live stock (double-decked cars being used for pigs and other small animals). Steel hopper cars, which discharge through the bottom, have immensely facilitated the handling of coal, and refrigerator cars vie with the canning process in their revolutionary effects on the distribution of meats and other perishable food products.

Railroad stations

City railroad stations have been transformed within the memory of middle-aged men from dingy barracks to magnificent monuments, affording a great variety of conveniences to the traveler. The luxuries of stations and parlor cars do not, however, represent the most substantial progress of the railroad. This is to be found, rather, in things to which the average traveler rarely gives a thought, such as the steel rail, the air brake and the interlocked switches and signals, which we have already mentioned, as well as a long list of labor-saving devices for the benefit of railroad workers rather than the traveling public. Only the other day, as it seems, section hands traveled over the road on hand cars propelled by their own muscular labor. Now they ride on motor cars, which are similar to the former hand cars, but fitted with gasoline engines. Once an army of men kept the road-bed true to shape and free from weeds. Today these tasks and many others are, as a rule, performed by machinery.

Street railways

The pioneer American railway cars were, as we have seen, drawn by horses, and hence it is not strange that the idea of using horse-drawn vehicles on rails in city streets should have suggested itself at an early date. The first street railway in the world began operation in New York City in 1833, and the second one in Boston in 1836. Several other American cities had their street railways with horses or mules as motive power, before the first one was seen in the Old World. This was

THE HORSE CAR

Replica of an old horse car exactly like those in use in Chicago in the days of horse-drawn cars on city streets.

Courtesy Chicago Surface Lines

TWO-CAR ELECTRIC RAILWAY TRAIN

Modern two-car train in actual operation on Milwaukee Avenue in Chicago.

built at Birkenhead, England, in 1860 by an American, George Francis Train.

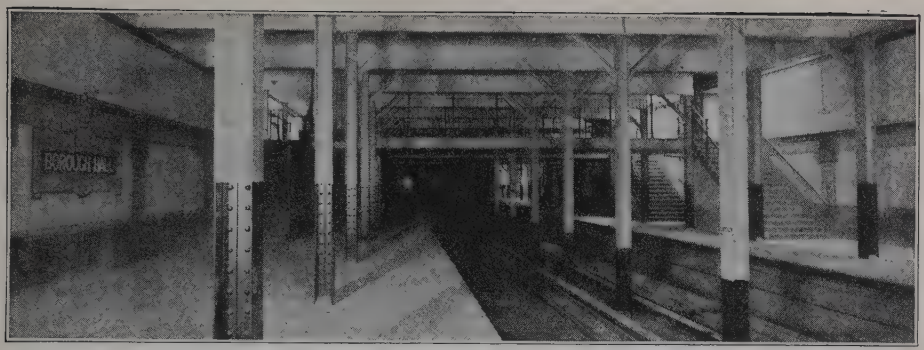
The horse car had no competitor on street railways until 1873 when the first cable car appeared, in San Francisco. Many cable lines were built in American cities during the next fifteen years. On such a line an endless steel cable runs in an underground conduit between the tracks. An arm from the car reaches down and grips the cable when the car is to be pulled along, and releases the cable when a stop is to be made. This system is now obsolete except on a few lines having very steep grades, where its use is still necessary.

The development of the electric railway in America dates back to the experiments of a Vermont blacksmith, Thomas Davenport, who operated a toy motor on a small railway in 1834. The idea remained in the experimental stage until after the perfection of the modern dynamo and motor in the seventies. It was then taken up in earnest by several American inventors, including Edison, but the first permanent electric railway in the world was opened in Germany in 1881. A successful line constructed by F. J. Sprague in Richmond in 1888 marked the beginning of the period in which electricity universally supplanted the horse on American street railways. Soon afterward the electric lines began to spread from the towns into the surrounding country and to link town with town, until today a network of "interurban" lines extends far and wide over the United States, operating not only passenger cars, but freight, express and mail cars, and, in a few cases, dining and sleeping cars.

With the rapid increase in the number of automobiles many electric lines have been forced out of business. There may be seen today hundreds of miles of abandoned track.

Another achievement of F. J. Sprague was the invention of the "multiple-unit" system of operating trains of electric cars. This system, in which the motors on all the cars are controlled from a single point and therefore start and stop at the same instant, may be seen to good advantage on elevated and subway lines. Sprague has been called with justice "the father of the electric street railway."

A TRANSCONTINENTAL STREAMLINE TRAIN



INTERIOR OF BOROUGH HALL (BROOKLYN) SUBWAY STATION

A station on the lines of the Interborough Rapid Transit Company of New York City. Glistening white tiled walls aid in lighting these underground stations.

UNDERGROUND ENGINEERING

THE problem of taking all the people where they want to go is a big one in our large cities. Another problem is the placing of the millions of telephone and telegraph wires and the miles and miles of water and gas pipes demanded by the modern city. Underground engineering with subway construction has come to the rescue in solving many of these problems.

THE THREE KINDS OF SUBWAYS

Subways, or passageways below the surface of the ground, are of three general types: (1) those for highway or railway traffic, (2) those for telephone, telegraph, light or power wires or cables, and (3) those for carrying water or gas pipes.

Perhaps the most important are the subways for passenger transportation, to do away with grade crossings, relieve surface congestion and afford more rapid transit. City after city has found, after the cost of buying new property has become prohibitive, that its surface transportation lines are hopelessly incapable of carrying the people. Many makeshifts have been used, but many of the plans for relief have only presented new and more difficult problems.

In many cities the congestion on the sidewalks is so great that walking is a waste of time. In parts of the City of New York an hour's hard walk at noon would accomplish less than a mile and a half.

SUBWAY PROBLEMS IN LARGE CITIES

Each large city presents a different situation for solution, as the result of conditions which have governed its growth. London's chief problem has been to secure a passenger carrying service connecting the constantly expanding districts, north, south and west, with the city business center and the busy port to the east.

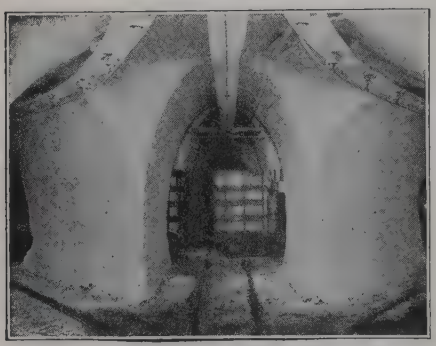
In Paris the problem has been partly a military one. It was necessary to connect the center with the outlying suburbs, which are set round about in a radiating fashion both within and without the fortifications, as well as to make possible the rapid concentration of troops to any part of the defences.

New York has had to face the most difficult situations of all. The original city, located on the long and narrow island of Manhattan, has extended to the north (the Bronx) and to the east

and southeast into Long Island (Brooklyn and Queens). There is also the problem of reaching the great cities across the Hudson River in New Jersey.

Boston and Philadelphia have comparatively short passenger subway systems. Chicago, while having no passenger subway, has an extensive freight tunnel.

The early subways, such as the London Metropolitan, were built on



THE CHICAGO TUNNEL

This great underground railroad runs under the streets of the central business district of Chicago at an average depth of forty feet below the street level. This subway is used for freight exclusively.

the cut and cover* system. Steam was the motive power used by the trains, and the use of fire under the boiler, with the resulting smoke, made frequent communication with the open air necessary.

The conditions which have led to the development of extensive subway systems have been, (1) accurate scientific knowledge of the surface layers of earth and stone and, (2) scientific advances in electricity. These, coupled with the skill of the engineer in following closely the discoveries of the scientists, have made possible the modern subways with their electrically driven trains.

Both Paris and New York present the same difficulty of rock at or near the surface with a certain thickness of subsoil and surface gravels to help out. A large proportion of the New York subway had to be blasted from the solid rock. New York has the added complication of the necessity of carrying the tunnels beneath wide and deep river channels.

Both London and Chicago are underlaid by a thick sublayer of plastic clay, well adapted for the digging of underground passageways.

THE CHICAGO TUNNEL

In Chicago following on the great extension of the railway systems of the United States it became necessary to find some means of handling the freight transfers of the twenty-five great trunk lines which meet there.

Chicago possesses some sixty or seventy miles of underground railways on which not a single passenger is carried, the work of transport being confined to merchandise, coal, cinders and rubbish. The track serves every street in the central business district. Goods for delivery to the railway terminals or other parts of the city are sent to the nearest collecting station and conveyed over the freight subway system. Ashes and coal are collected and distributed in the same way. The streets are relieved of freight traffic to the extent of about 3,000 tons daily.

Large business houses have private elevator shafts from the basements to the subway below. In recent years, wherever a large building has been erected, a temporary shaft has been constructed to the subway, and all the excavated material from the foundations has been fed straight into cars below, at an average depth of forty-five feet below the surface.

The tunneling for Chicago's freight subway was carried out at the rate

* In cut and cover construction the surface is cut, and, after lining, the tunnel is covered over.

Building Subways in Earlier Days, using "Cut-and-Cover" Method: Broadway, at City Hall Park

Under the Surface of Lower Broadway: How the Early Subways were Built

of some 300 lineal feet per day and the excavated material added a park of over twenty acres on the lake shore to the city's open spaces, free of cost to the community.

The tunnel averages forty feet below street level, and the temperature averages 50° the year round. There are 150 locomotives and 3,500 cars, and a 250 volts overhead trolley is used.

THE NEW YORK CITY SUBWAYS

New York City has the largest rapid transit system in the world. The city with its many millions presents a huge task for the carriers. There are four systems that run beneath the ground: the Interborough Rapid Transit Company, the Brooklyn-Manhattan Transit Corporation, the Hudson and Manhattan Railroad Company, and the new subway system owned by the city itself. The first unit of this system, known as the Eighth Avenue Subway, was completed in 1932 at a cost of $16,000,000 for each mile of construction. This system, which will eventually comprise fifty-seven miles of routes, is planned to connect the four boroughs of Bronx, Manhattan, Queens, and Brooklyn.

During the course of a normal business day the Interborough subway alone carries more than 2,000,000 passengers. Passing under the streets in express trains running at a high rate of speed is one of the experiences of the metropolis that is sure to impress the visitor. Whether one wishes to visit "east side, west side, all around the town," the subway or the "tube"* is ready to take him there in a hurry.

Men go below the surface to reach the trains that are to take them from the architectural wonder, the imposing Pennsylvania Station, east and west

*The "Hudson tubes" of the Hudson and Manhattan Railroad Company.

out of the city. After they have reached the trains they are dropped still farther underground, in order that they may pass beneath the bottom of the Hudson or the East River.

It is comparatively easy today to build subways, even when their construction involves tunneling under the beds of great rivers. But when the Pennsylvania Railroad tunnels under the Hudson and East Rivers, ninety-seven feet below high-tide level, were bored from the New Jersey shore across to and under Manhattan Island and thence to Long Island there was no engineering precedent for the undertaking.

The tunnels or tubes themselves consist of a series of iron rings, and the installation of every ring meant an advance of two and one-half feet. Eleven sections and a key piece at the top complete the circumference, and an entire ring weighs about fifteen tons. The cast-iron plates, or sections of the ring, have flanges at right angles to the surface, and it is through these that the successive rings are held together with bolts. The record progress in one day of eight hours was five of these rings, or twelve and one-half feet. Hydraulic rams, placed against the flanges every few inches around the tube, were used to push forward the huge shields with which the tunnels were bored. This type of shield weighed 194 tons.

To get out of New York City by means of the New York Central Railroad or the New York, New Haven and Hartford Railroad it is necessary to make use of the Grand Central Station, and again travelers drop down below the surface of the earth before they may start.

All of this underground business sounds dingy and dirty, but in reality there is much that is clean, bright and at-

ONE OF THE EXPENSIVE GRILL ROOMS FAR BELOW THE STREET LEVEL IN NEW YORK

tractive about New York's underground world.

Practically every skyscraper in New York City, and they are numbered by the hundreds, adds its quota to the "underworld" population of the city.

Before the greater structures—those that rear their way thirty, forty and fifty stories into the air—are really started, their foundations are sunk far down into the living rock which forms practically all of Manhattan Island. In many cases very comfortable apartments are to be found forty or fifty feet below the street surface, and there families are raised, children growing to maturity without ever having known a home above ground.

Practically all of the great newspapers of New York City have their batteries of presses below the surface of the earth. These mammoth machines must be away from all vibration and down on the solid rock of Manhattan are printed these journals of almost every known language.

In the great hotels of New York the mechanical departments are all far beneath the street surface. These departments are well worth visiting, and in most cases the hotel proprietors are only too glad to permit their kitchens, bakeshops, furnace-rooms, engine-rooms, and laundries to be inspected. These places ordinarily are as clean as any in the entire hotel.

Then, too, in most of the more expensive hotels the grillrooms are below stairs. On these rooms and in these rooms fortunes are spent by the proprietors and their patrons. A few years ago fashionable New York refused to put its feet below the street surface. Now it goes willingly into the lower levels, there to nibble at delicacies gathered from all over the world, the while listening to high-salaried cabaret performers who are assisted in their performances by world-famous orchestras.

Many of New York's greatest department stores are connected directly with the subways, as are also some of its theaters. A party of visitors in New York once lived for a fortnight in one of the most fashionable and expensive hotels in the city, spending most of their time shopping, sight-seeing and theater-going, and only once during the entire fourteen days passed into the open air of the outside world. From their rooms in the hotel they were dropped by elevator to the level of the subway. Through the subway they went to department stores, theaters, restaurants, museums and even to church. When they started for home they went by subway from their hotel to the Grand Central Station and did not get out into sunlight until their train had well started on its journey.

While the subway development of New York has progressed farther than that of any other city, yet the inevitable tendency, wherever population becomes congested and land values high, is to use the underground areas for business purposes.

THE HOLLAND VEHICULAR TUNNEL

On Nov. 13, 1927, at one minute after midnight, the Holland twin tubes under the Hudson River, from Canal street, New York City (Manhattan) to Twelfth street, Jersey City, were opened to commercial traffic. Each tube carries a twenty-foot roadway. The tunnel handled over 52,000 vehicles the first day. There are narrow sidewalks for pedestrians.

SUBWAYS FOR ELECTRICAL WIRES

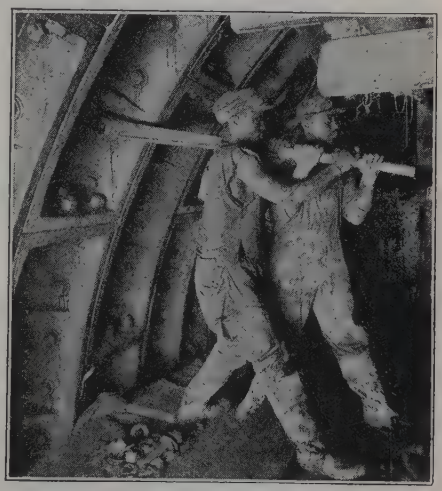
In many of the larger cities telegraph, telephone, light and power wires are buried in the earth in electrical subways. Pipes or tubes made of wood, earthenware or iron are cus-

tomarily used for the wires, which are generally insulated. Entrance to the tubes is had through manholes placed at regular intervals along the route. Sometimes the tubes are embedded in concrete.

How New York Gets Pure Water from the Catskills

Vast as is the New York rapid transit system, another and longer subway, or tunnel, is used to bring the waters of the Catskills to the metropolis. The water comes from the Esopus and Schoharie watersheds. The flow of Schoharie Creek is stopped by the new Gilboa dam which forms the Schoharie reservoir. This water, together with that from Esopus Creek, finds its way and is stored in the great Ashokan Reservoir at Kingston, N. Y. This reservoir has a capacity of 130,400,000,000 gallons—enough water to cover all Manhattan Island to a depth of thirty feet. In bringing the water to New York City there are fifty-five miles of earth-covered conduit, thirty-one miles of tunnel and six miles of steel-pressure tubing. The Kensico Reservoir, in Westchester County, about seventeen miles from the northern city boundary, serves as a storage supply so that the flow to the city may never be disturbed. The aqueduct ends at the Hill View Reservoir in the city of Yonkers, just north of the New York City line.

From Hill View the water is delivered into the five boroughs of the city by a circular tunnel cut in solid rock; it lies at depths of 250 to 750 feet below the surface of the streets, thus avoiding interference with buildings, transportation subways and sewers. The city tunnel is lined throughout with Portland cement concrete. It is the longest in the world for carrying water or for any other purpose. Twenty-five shafts, located where they do not interfere much with traffic, lead down to the tunnels and through these shafts the water is delivered into the street mains. The total cost of the completed Catskill water supply system is said to be about $180,000,000.



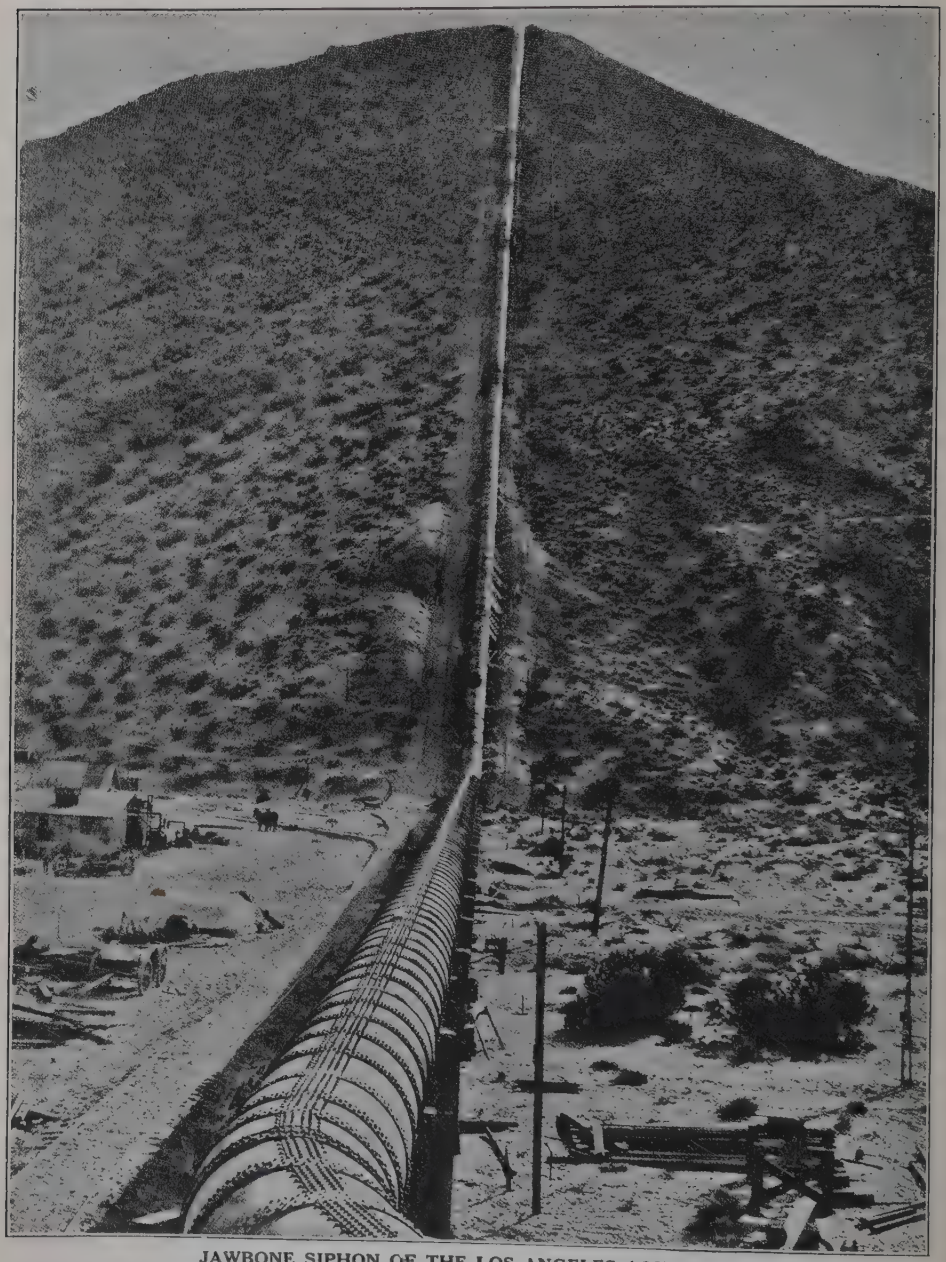
THE HOLLAND TUNNEL
Showing method of tightening bolts of tunnel lining by means of ratchet wrench.

How Los Angeles Gets Water from the Sierra Nevadas

Determined to secure a pure supply of water, the enterprising authorities of Los Angeles tapped a source high among the Sierra Nevada Mountains, starting at the Owens River. From that distant point, 233 miles away, the crystal water flows through different tunnels and a siphon until it reaches the water faucets of the city. For sixty miles the water flows by open canal to the Haiwee Reservoir. From this basin, 3,760 feet above sea level, the water flows through ninety-eight miles of covered conduit, forty-three miles of tunnel and twelve miles of steel siphon. The Los Angeles aqueduct cost $24,000,000.

Other Aqueduct Projects

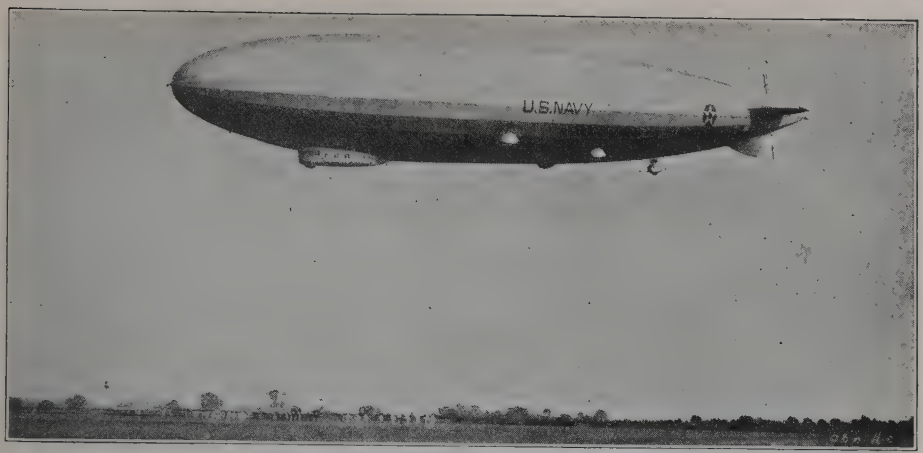
In 1934 the Hetch Hetchy aqueduct, which brings water to San Francisco from the Yosemite Valley, was completed.



JAWBONE SIPHON OF THE LOS ANGELES AQUEDUCT

Varying between seven and ten feet in diameter this enormous siphon has a total length of 8,135 feet and weighs 3,243 tons. The Los Angeles aqueduct is 233 miles long.

The Missouri Valley Water Tunnel, Kansas City, Missouri, was placed in operation in May, 1928. Boston is pushing forward a $65,000,000 water supply project involving the construction of a large aqueduct tunnel.



Official Photograph, U. S. Army Air Corps

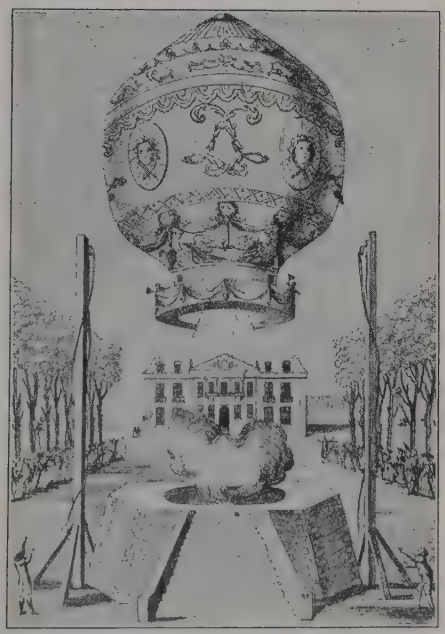
UNITED STATES AIRSHIP LOS ANGELES

NAVIGATION OF THE AIR

MAN has always envied the birds and desired to fly. As early as the year 67 A.D. men tried to build machines that would carry them through the air on wings. The Florentine artist, Leonardo da Vinci, in his "Treatise upon the Flight of Birds" (1505) revealed an extraordinary knowledge of his subject. The artist actually made a pair of wings which were made to flap by pedals worked with the feet. His efforts failed, however, and it was centuries before man learned enough about the laws of flight to fly.

SOME TERMS USED IN CONNECTION WITH AIR NAVIGATION

The term "aeronautics" covers all kinds of air navigation. If the craft is lighter than air it is known as an "airship." A simple gas bag is a "balloon" and if it is elongated and equipped so that it may be steered it is called a "dirigible" (from the Latin word meaning "to direct"). Airships may be non-rigid, semi-rigid or rigid, the latter being fitted with a framework that maintains the shape at all times. An "airplane" is heavier than air and depends upon one or more planes against which the air reacts when the airplane is driven. The pilot of any aircraft may be called



MONTGOLFIER BALLOON

The first practical balloon. It was made of coarse cloth covered with paper. It was filled with hot air and smoke.

an "aeronaut," although the driver of an airplane is commonly called an "aviator." A "parachute" is an umbrella-like contrivance which compresses the air and permits the descent of an aircraft passenger.

The development of the balloon

In 1783 in France there soared aloft the gorgeous painted balloon of the Montgolfier brothers. This first practical balloon was made of a coarse cloth covered with paper. It was thirty-five feet in diameter. It was inflated over a fire, being filled with hot air and smoke. As soon as the air cooled the balloon came down.

Later in the same year the Robert brothers of France sent up the first hydrogen-filled balloon. Since that time either hydrogen or helium has been the gas used in all airships. Hydrogen, formerly known as "inflammable gas," subjects the gas bag to the dangers of fire, a hazard which is removed when helium is used.

It is worthy of note that Benjamin Franklin was in France at the time these early ascensions were made, and he suggested the use of power.

Shortly after a Montgolfier balloon carrying passengers made an ascension near Paris. A number of accidents and the closing of the French ballooning schools by Napoleon led to the decline of the balloon-making industry. Showmen continued to use balloons. A few were employed by scientists in their investigations of weather conditions. Some were used in military work, as by the United States during the Civil War.

In 1836 Charles Green of England piloted the *Great Balloon of Nassau* to Nassau, Germany, a distance of 500 miles in eighteen hours. Green carried twelve passengers with him. This was the most remarkable air voyage of the time.

In 1863 Nadar of France built what was then and probably still is the biggest balloon in history, the *Le Geant*, a bag holding 450,000 cubic feet of gas and carrying forty passengers.

A balloon that is steered—the dirigible or airship

The early balloons rode the wind with no power to direct their course. Giffard, a French inventor, built a spindle-shaped gas bag in 1852, fitted it with a three-horsepower steam engine and steered his craft. He attained a speed of five miles an hour.

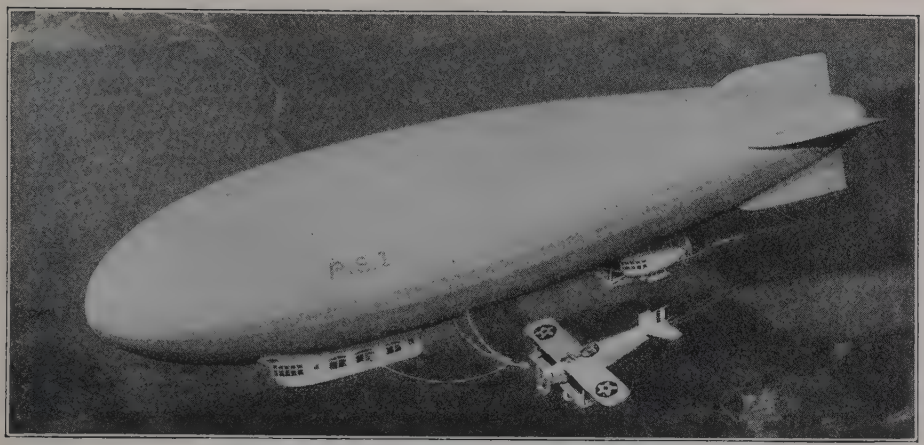
In 1882 another Frenchman, Tissandre, built a dirigible that maintained its position against a wind blowing at 6.8 miles an hour. When traveling with the wind Tissandre was able to move to one side or the other with ease. For power he used an electric battery and motors.

In 1884 a French government dirigible, designed by Renard and Krebs, traveled against the wind for the first time in history.

These earlier efforts paved the way for remarkable developments that came near the close of the nineteenth century and later. The chief improvement was the construction of suitable lightweight internal combustion motors.

Santos-Dumont with his rigid ships was a wealthy Brazilian who strove year after year for a prize offered to the first flyer to make the round trip from a Paris field to the Eiffel Tower and back in thirty minutes. In 1903 he accomplished his purpose. Within ten years Santos-Dumont contributed fourteen ships, each an improvement on its predecessor.

In Germany, Major von Parseval's motor-driven non-rigid airship was notable. It could easily be taken down and transported and inflated wherever military use required it. Some ships



AMERICA'S FIRST SEMI-RIGID AIRSHIP—THE RS-1
Artist's drawing of the *RS-1*. Note how an airplane may be picked up in flight.

of this type were stiffened with wood frames.

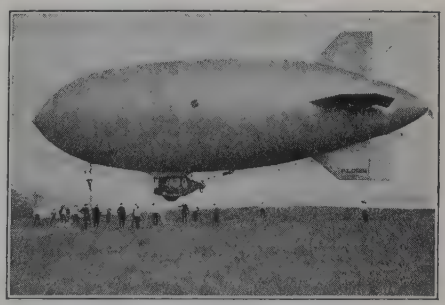
The Zeppelin, with its aluminum framework, has come to be known as a distinct form of the rigid type. Count von Zeppelin built the *Zeppelin I* in 1900. It contained a row of seventeen balloons packed like peas in a pod in a huge cylindrical shell 416 feet long and 38 feet in diameter. The crew and passengers occupied two aluminum cars which hung from the two ends and below the body of the craft. At the beginning of the World War there were thirty Zeppelins in Germany.

The British did little with the dirigible before the World War. In 1916 they built a series of small non-rigid airships commonly called "blimps" (from the official name, "B-limp") which were used mainly for observation purposes. Their *R-34* was the first airship to cross the Atlantic.

American Airships

Before the war America had done far less than Europe in airship development. Melvin Vaniman's dirigibles, the *America* and the *Akron* had both failed in their attempts to cross the Atlantic. By 1919 the useful non-rigid *C-5* had been developed, but it was destroyed in a storm 1,050 miles from Halifax in an attempted transatlantic flight.

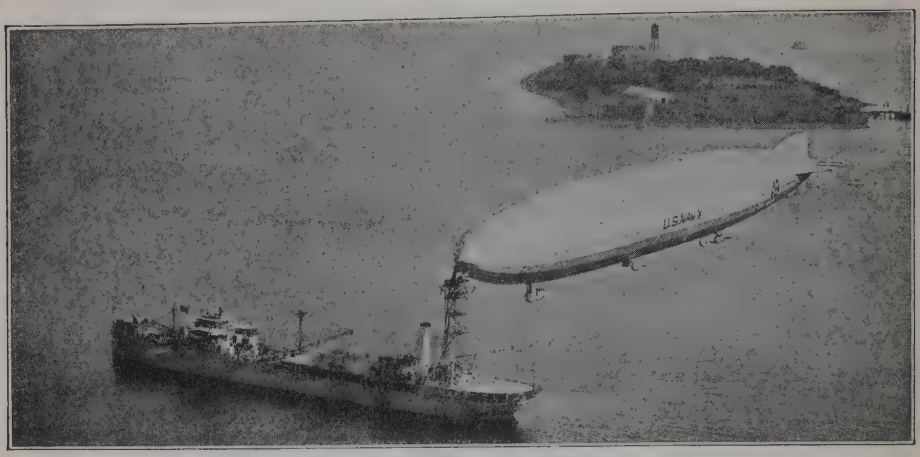
The United States ordered the *R-38* from England and renamed it *ZR-2*. It blew up in the air, after splitting lengthwise.



A SMALL AIRSHIP
The *Pilgrim*, a Goodyear non-rigid airship. It is only one fiftieth the size of the *Los Angeles*. It uses helium gas and has a speed of fifty miles an hour.

The *Roma* was bought from Italy and was destroyed by fire when it struck a high tension electric wire, due to an accident to one of its rudders.

The *ZR-1*, later named the *Shenandoah*, was built in the United States and was launched Sept. 4, 1923. This ship made many a successful flight, among which was a transcontinental



UNITED STATES AIRSHIP SHENANDOAH

The airship is shown moored to the mast of the *Patoka*, airship tender. The *Shenandoah* was destroyed in a storm, September 3, 1925.

trip of 9,000 miles in 1924. While on a flight, the *Shenandoah* was caught in a violent electrical storm and destroyed near Caldwell, Ohio, Sept. 3, 1925.

The German dirigible *ZR-3* was piloted from Friedrichshaven, Germany to Lakehurst, New Jersey and turned over to the United States on Oct. 15, 1923. It was accepted and later renamed the *Los Angeles*. It was built for commercial purposes and made many successful flights, but was decommissioned in 1932 due to insufficient appropriations to maintain it.

Heavier-than-air flying machines—airplanes and seaplanes

An airplane flies much as a kite does, except that instead of being pulled the airplane is thrust forward by a motor and propellers. The wings of the plane provide a broad flat surface to meet the resistance of the air. The front edges tilt up and the wind rushing past tends to make the plane climb. The front of the wing of an airplane has a hump which shoots the air upward. Speeding through the air, the tremendous volume of air that is deflected upward exerts a pull very similar to the pull in a vacuum cleaner. It pulls on the top surface of the wing and tends to draw the back part of the wing up in the air after it. A perfectly flat surface forced against the air at great speed with the front edge tilted would naturally rise, but it is the vacuum that is responsible for the unusual lifting power of the airplane's wings.

When Leonardo da Vinci wrote his treatise on the flight of birds he expressed some ideas that have been used since in building and flying gliders, machines which travel from a height downward. The first record of such a flight is that of the French locksmith, Besnier, who is said to have flown a glider.

In 1849 Stringfellow of England made and flew a model airplane equipped with a small steam engine. This was the first plane to fly under its own power.

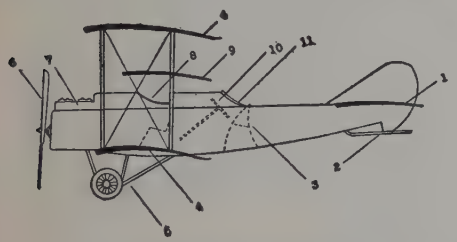
Otto Lilienthal of Germany watched the buzzard in its flight and devised therefrom plans for gliders. He made more than 2,000 glides but finally met his death near Berlin in 1891.

In America, Octave Chanute, sometimes called the "father of gliding

flights," built and flew several large gliders in 1896 and 1897.

Samuel P. Langley (see story of Langley in Vol. VI), an American scientist, in 1891 began work on what he called an "aerodrome." On May 6, 1896, his little craft, too light to carry a man, flew out over the Potomac River in Washington for more than a minute, defying gravitation to pull it down. Then it settled down on the water.

After a long study of the principles involved, the Wright brothers, Orville and Wilbur, made their first trip in



Courtesy U. S. Bureau of Education

SIDE VIEW OF AIRPLANE

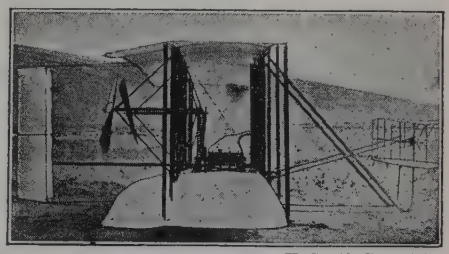
1—Elevator. 2—Land skid. 3—Fuselage. 4—Supporting frame. 5—Chassis. 6—Propeller. 7—Engine. 8—Passenger's seat 9—Ailerons. 10—Control. 11—Aviator's seat.

a glider in 1900 at Kill Devil Hill, North Carolina. Their machines resembled those of Lilienthal and Chanute. Then the Wright brothers put power into their machines. On Dec. 17, 1903, at Kitty Hawk, North Carolina, Orville Wright flew for twelve seconds—the first flight in history where a machine carried a man through the air without reduction of speed and finally landed him at a point as high as that from which he started.

Santos-Dumont, Bleriot and others in Europe were developing airplanes in the early years of the twentieth century. In 1908 Curtiss, an American, flew the first plane from the ice; he worked out many devices for landing.

HYDROPLANES AND FLYING BOATS

A hydroplane is an airplane fitted with a base that enables it to skim along on the surface of the water with almost no water displacement. A flying boat is an airplane attached to what is actually a boat which sinks



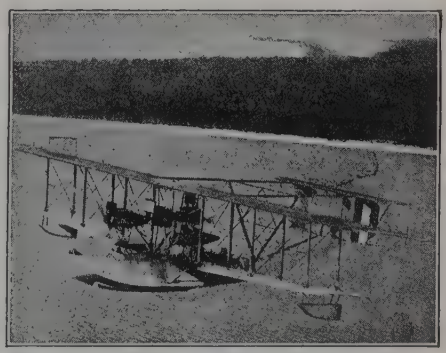
U. S. Air Corps Photo

ORIGINAL WRIGHT PLANE

The machine in which Orville Wright made his historic flight at Kitty Hawk, North Carolina, on Dec. 17, 1903.

in the water; it requires, therefore, much more power to attain even less speed than a hydroplane.

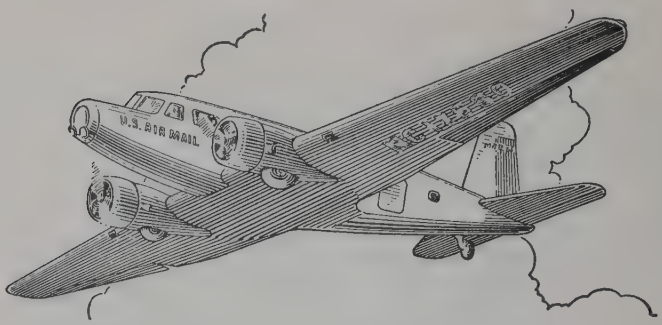
It remained for Glenn H. Curtiss, mentioned before, to solve the problem of flying at high speed on the surface



THE NC-4

Developed by the United States during the World War for long distance scouting. The *NC4* was the first plane to cross the Atlantic Ocean.

of the water. In 1910 he operated his 40-horse-power flying boat successfully on Lake Keuka. The small motor was too weak for air flights, but by 1911 and 1912 Curtiss had constructed machines with sufficient power to travel through the air.

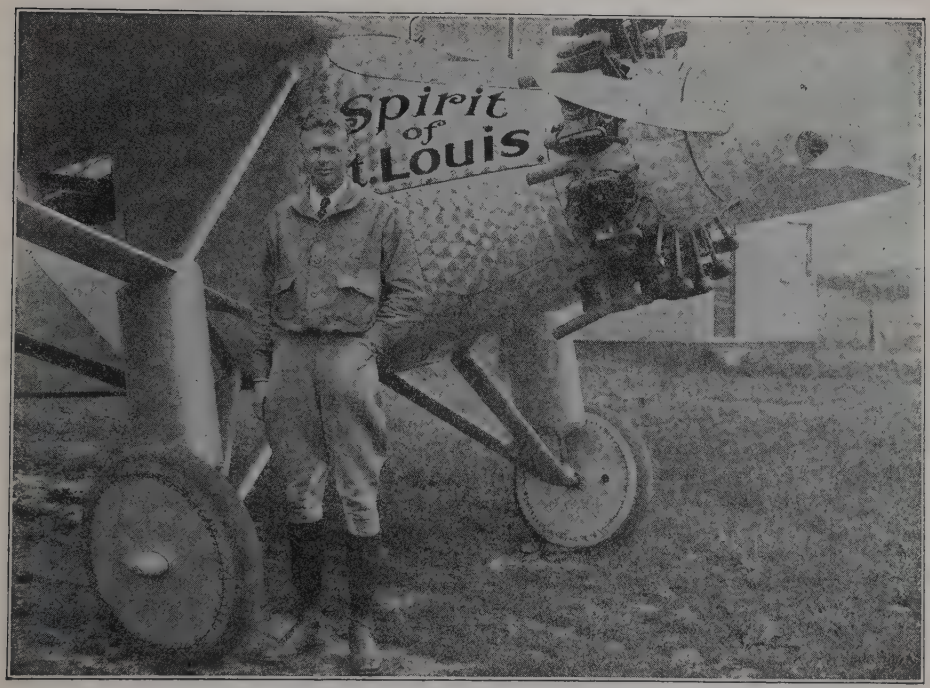


These types have been adopted by the United States and other nations for their navies. The *NC-4*, first plane to cross the Atlantic, was a Curtiss flying boat.

THE AIR MAIL

On May 15, 1918, an airplane rose from New York and sailed away to Washington, inaugurating the Air Mail Service. Transcontinental service began when a plane left Mineola Field on Long Island, September 8, 1920. This mail was delivered by another plane in San Francisco on September 11. This transcontinental service was speeded up so that a letter mailed in New York on Monday could be delivered in San Francisco on Wednesday. By the end of 1932 regular air mail schedules were in operation between practically all of the large cities of the United States. During 1934 almost eight million pounds of mail and almost three million pounds of express were carried by plane. This service is of immeasurable aid in transacting such business matters as require speedy communication.

TRAINING PLANE
Used in the World War to train American soldiers to fly.



LINDBERGH AND THE SPIRIT OF ST. LOUIS

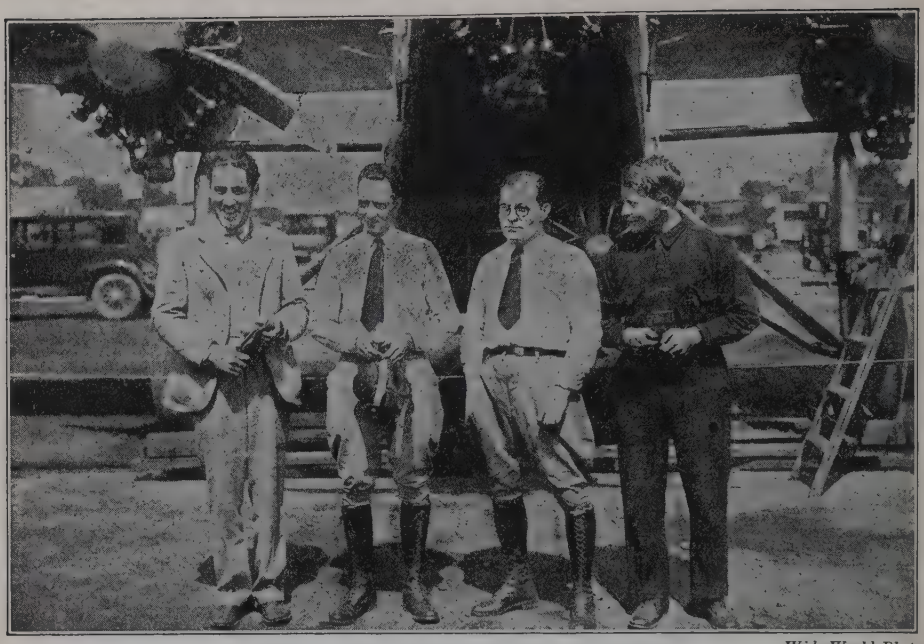
The famous "We" of transatlantic fame. Colonel Lindbergh in the *Spirit of St. Louis* later toured the United States and visited many of our sister nations to the south. Then, on April 30, 1928, he took his airplane on its last flight to Washington, where it was deposited in the Smithsonian Institution.

CROSSING THE ATLANTIC IN AN AIRPLANE

In 1913 the London *Daily News* offered a prize of $50,000 for a transatlantic flight. After two English planes had failed, an American flying boat, the *NC-4* (Navy-Curtiss), a joint product of the United States Navy and the Curtiss Engineering Corporation, succeeded in crossing the Atlantic, but not without making intermediate stops, seven in all. The start was made from Rockaway Point, N. Y., on May 8, 1919, and Plymouth, England, was reached May 31. The *NC-4* made sixty miles an hour on the water and ninety in the air. Four Liberty motors were used.

The first non-stop transatlantic flight was made by British aviators. On June 14, 1919, Captain J. Alcock and Lieutenant A. W. Brown took off from St. John's, Newfoundland. They used a huge Vickers-Vimy plane fitted with two Rolls-Royce motors. In spite of the fact that unfavorable weather conditions permitted the taking of but three observations during the entire flight, the plane landed at Clifden, Ireland, on June 15, a total flight time of sixteen hours and twelve minutes. This non-stop flight fulfilled the conditions and won the *Daily News* $50,000 prize.

The first non-stop, one-man flight ever made across the Atlantic was that of the American "Lone Eagle" aviator, Captain Charles A. Lindbergh. From San Diego he crossed the continent in his Ryan monoplane, *Spirit of St. Louis*, which was fitted with a single nine-cylinder Wright "Whirlwind" air-cooled motor. He waited a few days at Roosevelt Field, Long Island, and then, suddenly, at 7:52 on Friday



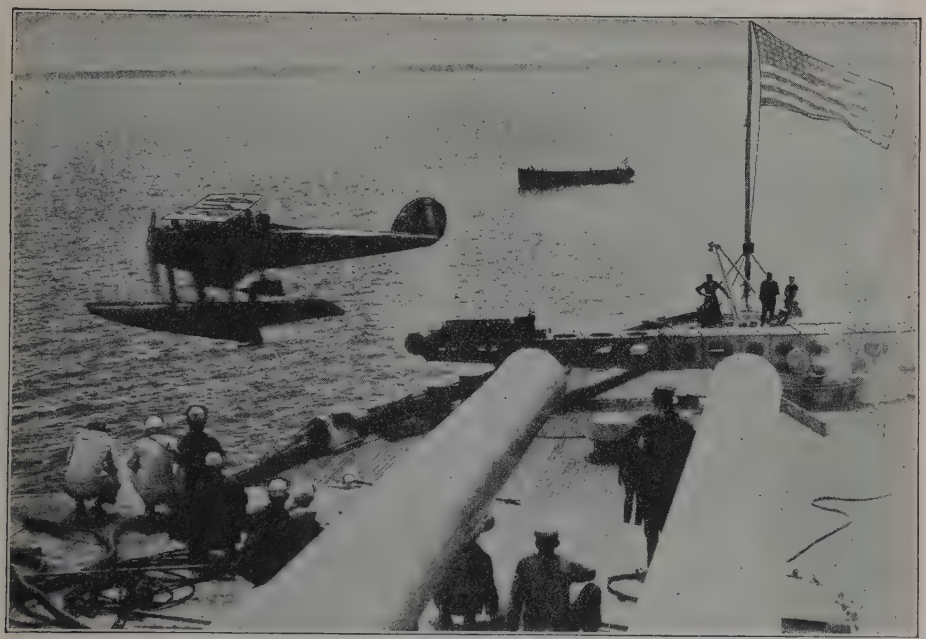
BYRD AND HIS TRANSATLANTIC CREW *Wide World Photos*

Commander Byrd and his three companions with their giant Fokker monoplane, *America*. They crossed the Atlantic, but made a forced landing on the Normandy coast. From left to right: Bert Acosta, Commander Richard E. Byrd, Lieutenant George O. Noville, Bernt Balchen.

morning, May 20, 1927, with a shout of "Well, let's go!" the twenty-five-year-old flyer was off on his lone flight. Through fog, rain and sleet he flew, guiding his craft with the aid of an earth inductor compass. At 10:24 Saturday evening Lindbergh swooped carefully down at Le Bourget Field, Paris, to receive the thunderous welcome of those waiting on the famous French flying field and to be acclaimed all over the world for his remarkable achievement. The flight was completed in thirty-three and one-half hours and the distance, as given by the U. S. Geological Survey, was 3,610 miles.

Within a fortnight, in the forty hours between the early morning of June 4 and the evening of the next day, another transatlantic flight was accomplished by Clarence Chamberlin, piloting a Bellanca monoplane, likewise equipped with a single Wright air-cooled engine. Chamberlin started from Roosevelt Field and landed near Eisleben, Germany. Charles Levine, owner of the plane and assistant pilot, was carried as a passenger. The Bellanca plane was made in Paterson, New Jersey. This flight gave further evidence of the efficiency of the Wright motor and American airplane construction.

A dramatic crossing that fell barely short of its goal was that made by Commander Richard E. Byrd and his three companions, Acosta, Noville and Balchen, in the giant monoplane *America*, a Fokker plane equipped with three engines. After crossing the Atlantic in nineteen hours of fog, the flyers were unable to discern Paris. After circling about in the rain and mist a forced landing was made on the Normandy coast.



A SEAPLANE TAKES OFF *United States Navy Photograph*
The seaplane has just been catapulted from the deck of the battleship.

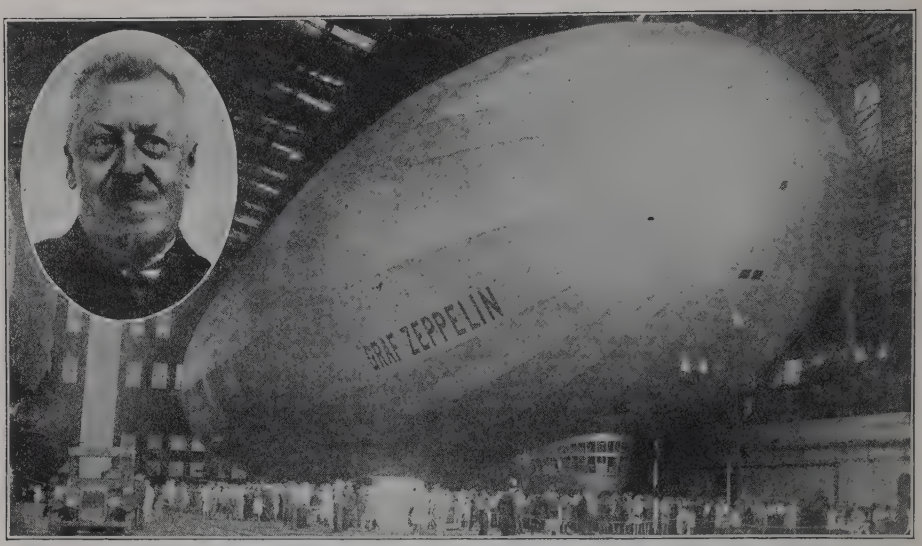
On May 20, 1932, Amelia Earhart Putnam flew from Newfoundland to Ireland in thirteen and a half hours. This was the first solo Atlantic crossing by a woman.

Attempts to fly westward from Europe to America were unsuccessful until the spring of 1928. Baron Ehrenfried Gunther von Huenefeld and Captain Herman Koehl started from Berlin on March 26 in the Junkers monoplane, *Bremen*, and landed at Balmoral Field in Ireland on the same day. There they added to their crew Major James Fitzmaurice, Commandant of the Air Forces of the Irish Free State. They left Ireland on April 12 and reached America on the following day, although they were forced to land on bleak Greenly Island, off the coast of Labrador. The *Bremen* flyers made a tour of the United States, where large crowds greeted them everywhere, hailing their visit as another link in the friendship of the nations represented.

THE FIRST ROUND-THE-WORLD FLIGHT

On the morning of March 17, 1924, four Douglas airplanes carrying American flyers rose from the field at Santa Monica, California, and the first world flight had begun. By observing the map their route and stops may be seen. In Alaska Flight Commander Martin met with engine trouble, installed a new engine, and then in a snowstorm around a mountain near Port Moller had his plane wrecked beyond hope of repair. Thus the plane *Seattle* dropped out of the race and, at the suggestion of Major Martin, Lieut. Smith assumed command.

The flyers had reached the end of the Aleutian Islands. Ahead stretched a dangerous ocean voyage of 800 miles. Pontoons had been substituted for wheels and the trip to the Kuriles



FIRST AIRSHIP TO FLY AROUND THE WORLD

The *Graf Zeppelin*, first lighter-than-air craft to fly around the world. The inset is a portrait of Dr. Hugo Eckener, commander of the ship. The dirigible is shown in the hangar at Lakehurst, N. J., just before the start of the flight.

was begun. A forced landing compelled the men to anchor their planes on the water off the Kamchatka coast for the night. The Kuriles were reached the next day.

At Shanghai, wheels replaced the pontoons. Stops were made at Hongkong, Bangkok, Rangoon, Calcutta, Allahabad and other places. In a fall, while on the ground, Lieut. Smith fractured two ribs, but he kept on. In order, Persia, Baghdad, Aleppo and Constantinople were reached.

Through Europe, by way of Bucharest, Vienna and Strasbourg, the airmen reached Paris on Bastile Day, July 14. From London the flight continued to Hull where the sea-going pontoons were again put on. Off the Faroe Islands the Plane *Boston* was wrecked, leaving the *Chicago* and the *New Orleans* to continue the flight. The two planes reached Iceland, then Greenland, Labrador, Newfoundland and, on September 6, Boston. By easy stages the flight continued and ended at Seattle on September 28.

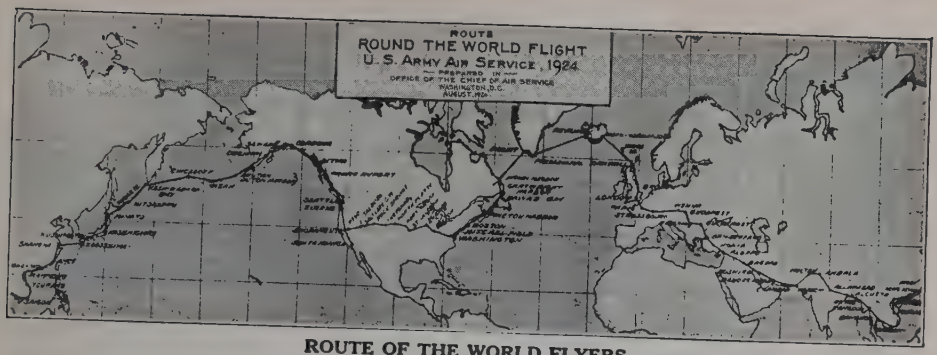
First Airship to Circle the Globe

In August, 1929, the German dirigible, *Graf Zeppelin*, captained by Dr. Hugo Eckener and with a crew of thirty-three, made the first world flight of an airship. The start and finish were at Lakehurst, N. J. The time was twenty-one days, seven hours and twenty-six minutes. The *Graf Zeppelin* was completed in the Zeppelin works at Friedrichshafen, Germany.

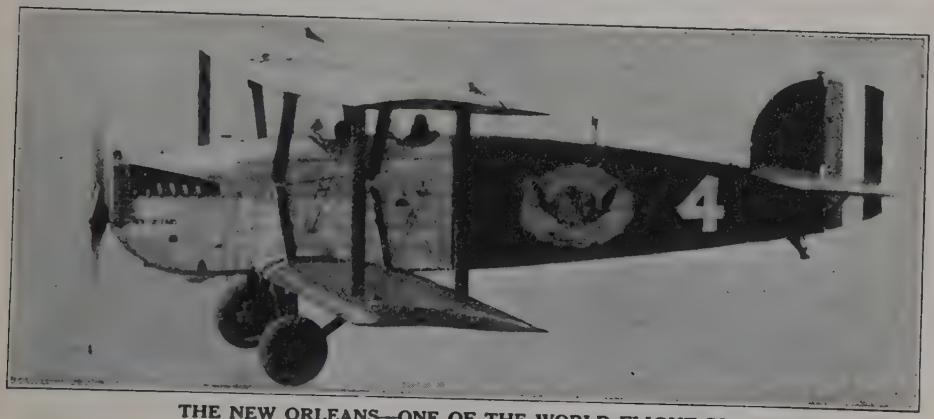
In 1936, the *Hindenburg*, giant German dirigible went into commission and made ten transatlantic crossings.

Uses for Aircraft

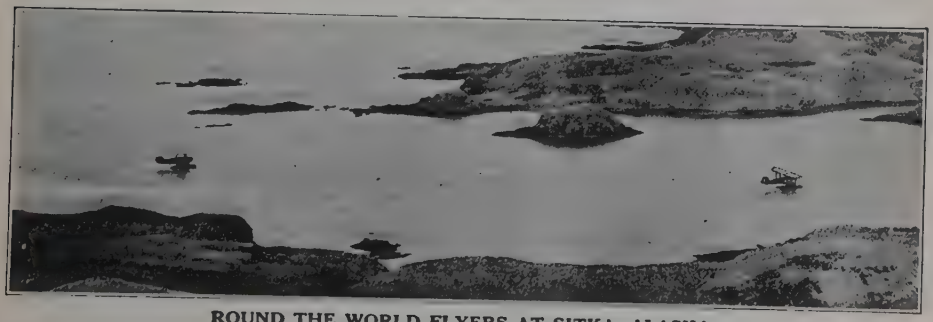
Balloons, dirigibles and airplanes are invaluable in times of war, assisting both the army and the navy. More and more the mails are being carried by airplane. All varieties of aircraft are being used for commercial and sport purposes. Elsewhere in these volumes you will read about the effective uses of airplanes in spraying cotton to control the ravages of the destructive insect, the cotton boll weevil.



ROUTE OF THE WORLD FLYERS



THE NEW ORLEANS—ONE OF THE WORLD FLIGHT PLANES



ROUND THE WORLD FLYERS AT SITKA, ALASKA

ROUND THE WORLD FLYERS OVER NEW YORK

Recent aircraft achievements

The great advances made in aviation in the twentieth century were strikingly illustrated by the round-the-world flight of Wiley Post and Harold Gatty in June, 1931. Their time was 8 days, 15 hours and 50 minutes.

On November 20, 1933, Lieutenant Commander Thomas G. W. Settle and Major Chester L. Fordney established an official altitude record of 61,236 feet in a balloon at Akron, Ohio.

In 1934 Russian balloonists set an unofficial record of 72,000 feet, but crashed and were killed.

On October 23, 1934, Lieutenant Francesco Agello made a seaplane record of 440 miles per hour in Italy.

In 1935 the huge Pan-American Clipper made her first roundtrip flight between San Francisco and Hawaii, making the crossing to Hawaii in 18 hours, 37 minutes on April 17.

The giant dirigible *Macon* was launched in 1933. It was destroyed off the coast of California in 1935.

On January 13, 1935, Amelia Earhart made a solo flight from Honolulu to Oakland, California, in 18 hours, 16 minutes. Later in the year she flew solo from Burbank, California, to Mexico City, and on to New York.

On November 11, 1935, Captains A. W. Stevens and O. A. Anderson broke the stratosphere record by ascending in a balloon, near Rapid City, South Dakota, to a height of 72,395 feet.

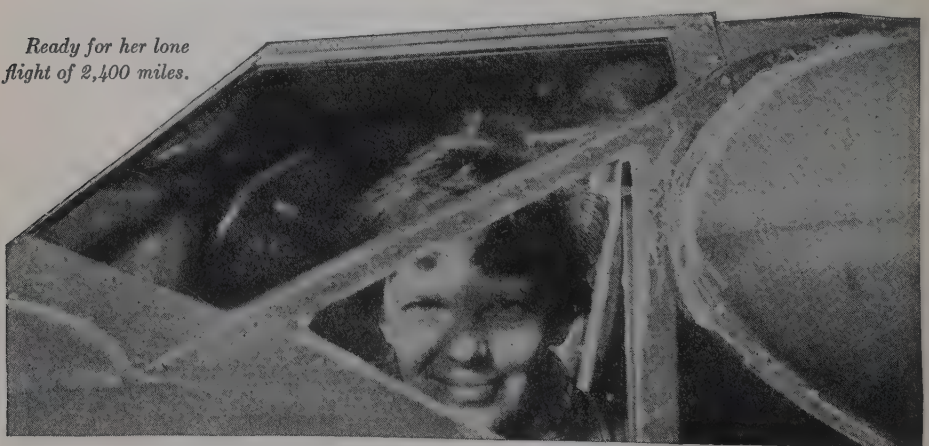
On December 19, 1936, Major Alexander P. De Seversky set a new speed record for amphibions at 209.4 miles an hour at Miami.

On January 19, 1937, Howard Hughes set a new record, flying from Los Angeles to Newark in 7 hours, 28 minutes and 25 seconds.

Travel through the air and what it means for the future

With navigation of the air there has dawned a new day for exploration, transportation and commerce. Its dawn may mark the birth of a new civilization. Air travel brings contacts between distant peoples, and understanding increases with contact. In contemplating the great significance of air travel we may well listen to the wisdom of Macaulay, who said: "Of all inventions, the alphabet and the printing press excepted, those inventions which abridge distance have done most for civilization."

Ready for her lone flight of 2,400 miles.



Acme Photo

AMELIA EARHART IN HAWAII BEFORE HER FLIGHT TO CALIFORNIA

A TABLE OF GREAT INVENTIONS

Invention	Date	Inventor	Country
Adding Machine	1642	Blaise Pascal	France
Air Brake	1869	George Westinghouse	United States
Airplane	1896	Samuel P. Langley	United States
Airship	1852	Henri Giffard	France
Arc Lamp	1808	Sir Humphry Davy	England
Babcock Test	1890	Stephen M. Babcock	United States
Barometer	1643	Evangelista Torricelli	Italy
Bicycle	1840	Kirkpatrick Macmillan	Scotland
Cable, submarine	1866	Cyrus W. Field	United States
Camera Obscura	1569	Giamba Hista della Porta	Italy
Carding Machine, textile	1760	James Hargreaves	England
Cash Register	1879	James Ritty	United States
Celluloid	1869	J. W. and Isaac Hyatt	United States
Compass, mariner's	2000 B.C.	Unknown	China
Cotton Gin	1794	Eli Whitney	United States
Clock	1379	Henry De Vick	Germany
Cream Separator	1879	Carl G. P. DeLaval	Sweden
Dictograph	1907	K. M. Turner	United States
Diesel Engine	1893	Rudolph Diesel	Germany
Dynamite	1866	Alfred Nobel	Sweden
Dynamo-Electric Machine	1831	Michael Faraday	England
Electric Furnace			
Arc type	1853	Pichou and Johnson	France & England
Resistance type	1880	W. Borchers	Germany
Electric Railway			
Working model	1834	Thomas Davenport	United States
Successful full size	1879	Siemens and Halske	Germany
Electromagnet	1823	William Sturgeon	England
Elevator, power	1852	Elisha G. Otis	United States
Flying Shuttle	1733	John Kay	England
Fourdrinier Paper-making Machine	1798	Louis Robert	France
Galvanometer	1819	Hans Christian Örsted	Denmark
Gas Engine	1877	N. A. Otto	United States
Gunpowder	1270	Roger Bacon	England
Gyroscope	1744	Serson	France
Hydroplane	1911	Glenn H. Curtiss	United States
Hygrometer	1676	Coniers	France
Incandescent Lamp	1879	Sir Joseph Swan	England
	1879	Thomas A. Edison	United States
Interferometer	1887	A. A. Michelson	United States
Leyden Jar	1745	E. G. von Kleist	Germany
Lightning Conductor	1752	Benjamin Franklin	United States
Linotype	1885	Ottmar Mergenthaler	United States
Lithography	1798	Aloys Senefelder	Germany
Locomotive, Steam			
First on rails	1804	Richard Trevithick	England
Commercially successful	1825	George Stephenson	England
Mantle Burner, gas	1885	Karl Auer von Welsbach	Austria
Matches, friction	1827	John Walker	United States
Microscope, compound	1590	Zacharias Janssen	Netherlands
Monitor	1861	John Ericsson	Sweden & U. S.
Monotype	1887	Talbert Lanston	United States
Motion Picture Machine, kinetoscope	1894	Thomas A. Edison	United States
Mowing Machine	1812	Peter Gaillard	United States
Piano (pianoforte)	1709	Bartolommeo Cristofori	Italy

A TABLE OF GREAT INVENTIONS—Continued

Invention	Date	Inventor	Country
Plow, first American patent	1797	Charles Newbold	United States
Power Loom	1785	Edmund Cartwright	England
Printing			
Block	50 B.C.	Unknown	China
Movable type	1450	Johannes Gutenberg	Germany
Pulmotor	1911	A. B. Dräger	Germany
Radiotelegraphy	1896	Guglielmo Marconi	Italy
Radiotelephony	1915	Bell Company engineers	United States
Rayon	1888	H. deChardonnet	France
Reaping Machine	1834	Cyrus McCormick	United States
Safety Lamp, miner's	1815	Sir Humphry Davy	England
Screw Propeller	1839	John Ericsson	Sweden & U. S.
Sewing Machine	1846	Elias Howe	United States
Smokeless Powder	1884	Paul Vieille	France
Spectroscope	1859	Kirchoff and Bunsen	Germany
Spinning Frame	1769	Sir Richard Arkwright	England
Spinning Jenny	1764	James Hargreaves	England
Spinning Mule	1779	Samuel Crompton	England
Steamboat			
First	1787	John Fitch	United States
Commercially successful	1803	Robert Fulton	United States
Steam Engine			
With cylinder and piston	1690	Denis Papin	France
With separate condenser	1769	James Watt	England
Steel			
Bessemer process	1847	William Kelly	United States
	1855	Sir Henry Bessemer	England
Open-hearth process	1868	Siemens and Martin	England
High speed	1900	Taylor and White	United States
Stethoscope	1819	René T. H. Laënnec	France
Street Railway, horse-drawn cars	1833	John Stephenson	United States
Submarine			
First type	1624	Cornelis van Drebbel	Netherlands
Modern type	1898	John P. Holland	United States
Talking Machine	1877	Thomas A. Edison	United States
Telautograph	1890	Elisha Gray	United States
Telegraph	1837	Samuel F. B. Morse	United States
Telephone	1876	Alexander G. Bell	United States
Telescope	1608	Hans Lippershey	Netherlands
Thermometer	1592	Galileo	Italy
Turbine, steam			
"Impulse" type	1883	Carl P. G. DeLaval	Sweden
"Reaction" type	1884	C. A. Parsons	England
Typewriter	1714	Henry Mill	England
Vacuum Bottle	1893	James Dewar	England
Vacuum Cleaner	1902	David T. Kenney	United States
X-Ray Machine	1895	W. C. Roentgen	Germany

A TABLE OF CHEMICAL ELEMENTS

CHEMICAL ELEMENTS

A tabulated statement of the occurrence, preparation, properties and uses of all important elements.

Abbreviations:—At. wt., atomic weight; M. wt., molecular weight; Va., valence; S. G., specific gravity; M. P., melting point; B. P., boiling point. All temperatures are centigrade.
Definitions of Chemical Element, Atomic Weight, Symbol, Formula, and Electrolysis will be found at the end of the Table.
Note:—The M. wt. of gases divided by 28.95 gives the density compared with air.

Aluminum, Al.
At. wt. 27.1.
Va. III.
S. G. 2.6 M. P. 658°.

Occurrence. Very abundant in clays, feldspars and many other silicate rocks; also as the oxide in emery, ruby, sapphire, etc.
Preparation. Electrolysis of the purified oxide dissolved in molten cryolite.
Properties. Silver white, ductile, malleable at 120°, high tensile strength, the best conductor in proportion to weight. Stable at ordinary temperatures, attacked only by strong acids, except nitric acid, and by caustic alkali. Has a powerful affinity for oxygen at high temperatures, therefore it is a most powerful reducer of other oxides, generating high temperatures in the action, which are exceeded only by the electric arc. Also used for cooking utensils, electrical conductors, and paint. Clays and alum are very important compounds.

Antimony, Sb.
At. wt. 120.02.
Va. III and V.
S. G. 6.7.
M. P. 630°.

Occurrence. Mostly as stibnite (Sb_2S_3).
Preparation. Roasting stibnite to oxide and reducing with carbon.
Properties. White metal, brittle, strongly crystalline. Molten metal expands on solidification, and its alloys give, therefore, sharply defined castings, *e. g.*, type metal. Stable in air, burns when heated, and unites readily with the halogens. It is used mostly in alloys, *e. g.*, type metal, Britannia metal and Babbitt metal (for bearings).

Argon, A.
At. wt. 39.86.
M. wt. 39.86.
B. P. 186°.

Occurrence. About 1% of the air.
Preparation. Carbon dioxide, water vapor, oxygen and nitrogen are successively removed from air by absorption. The residue is mostly Argon.
Properties. Monatomic gas, absolutely inert, enters into no chemical combinations. Identified by its characteristic spectrum.

Arsenic, As.
At. wt. 75.
Va. III and V.
S. G. 5.7.

Occurrence. Free, arseno pyrite (FeAsS), and the sulphides orpiment and realgar.
Preparation. Roast ores, and reduce oxide with carbon.
Properties. Steel gray, tarnishes to dull gray, coarsely crystalline. Sublimes at 450°. Burns with pale blue flame, combines readily with the halogens. The most important compounds are white arsenic (As_2O_3) and its derivatives, and the salts of arsenic acid (H_3AsO_4). Used mostly for insecticides, also in medicine.

Barium, Ba.
At. wt. 137.37
Va. II.
S. G. 3.6.

Occurrence. Barytes ($BaSO_4$) and witherite ($BaCO_3$).
Preparation. Electrolysis of the molten chloride.
Properties. A silver-white metal, decomposes water, very active. Its vapors give a green flame. Hence it is used in pyrotechny. Important compounds are BaO_2, used in manufacturing oxygen and hydrogen peroxide, and $BaSO_4$, used in paints as an inferior substitute for white lead. $BaSO_4$ is highly insoluble.

Bismuth, Bi.
At. wt. 208.
Va. III.
S. G. 9.9.
M. P. 266.5°.

Occurrence. Free, and as trioxide, and trisulphide.
Preparation. Roasted in air and reduced with carbon.
Properties. Bright crystalline metal with pinkish tint; brittle. Stable in air, burns when heated. Used in alloys with low melting points. The subnitrate is used in medicine.

Boron, B.
At. wt. 11.
Va. III.
S. G. 2.4.

Occurrence. In boric acid and borax.
Preparation. The oxide is heated with magnesium.
Properties. A greenish black powder. Boric acid (H_3BO_3) and borax ($Na_2B_4O_7$) are important compounds.

CHEMICAL ELEMENTS — Continued

Bromine, Br.
At. wt. 79.92.
M. wt. 160.
Va. I.
S. G. 3.2.
B. P. 59°.

Occurrence. In sea water and salt deposits, as bromides.
Preparation. Bromides are treated with sulphuric acid and manganese dioxide, and the Br. distilled off.
Properties. Dark red liquid, bad odor, very corrosive and poisonous. Combines with most elements but with less energy than chlorine. Used in preparation of dyes. Bromides are used in medicine and photography.

Cadmium, Cd.
At. wt. 112.4.
Va. II.
S. G. 8.6.
M. P. 321.7°.

Occurrence. In Zinc ores.
Properties. A silver-white metal, burns in air, and is fairly active. Uses, in alloys with low M. P. The sulphide is a yellow pigment. The iodide is used in medicine.

Cæsium, Cs.
At. wt. 132.81.
Va. 1. S. G. 2.4.

Rare element, strongly resembling potassium. The most active of the metals.

Calcium. Ca.
At. wt. 40.09.
Va. II.
S. G. 1.54.
M. P. 760.

Occurrence. As carbonate in limestone, marble, chalk, etc. As sulphate in gypsum, as phosphate, fluoride, and in many silicates.
Preparation. Electrolysis of the fused chloride.
Properties. A white crystalline metal. Decomposes water, burns in air, and is very active. Uses: Yields many useful compounds, *e. g.*, lime, which is the oxide; slaked lime, the hydroxide; bleaching powder and calcium carbide.

Carbon, C.
At. wt. 12.
Va. IV.
S. G. 1.9—3.5.

Occurrence. In two crystalline forms, diamond and graphite, and in several amorphous forms: charcoal, coke, lamp black, gas carbon, and coal. Each has its peculiar important uses.
Properties. Very stable at ordinary temperatures, very active toward oxygen at high temperatures. It forms carbon dioxide, the basis of carbonic acid, and the poisonous monoxide. The compounds of carbon form the field of organic chemistry.

Cerium, Ce.
At. wt. 140.25.
Va. III and IV.
S. G. 7.0.

Occurrence. In cerite and monazite.
Preparation. Electrolysis of the molten chloride. Burns with dazzling brightness. One per cent of the dioxide is used in Welsbach mantles.

Chlorine, Cl.
At. wt. 36.46.
M. wt. 71.
Va. I, V and VII.
B. P.—33 6°.

Occurrence. In salt (NaCl) and other chlorides.
Preparation. Electrolysis of chlorides, or oxidation of hydrochloric acid.
Properties. A greenish-yellow gas of intensely bad odor, very corrosive to mucous membranes, combines with most elements with great energy. Used for bleaching and disinfecting.

Chromium, Cr.
At. wt. 52.
Va. II, III and VI.
S. G. 6.9.
M. P. 1515°.

Occurrence. As chromite ($FeCr_2O_4$).
Preparation. By reducing the oxide with aluminum.
Properties. A steel gray, brittle and very hard metal. Stable in air, burns at high temperatures. Used in alloys and in chrome steel. Potassium dichromate, $K_2Cr_2O_7$, has many uses, in making pigments, in tanning and dyeing, and as an oxidizing agent.

Cobalt, Co.
At. wt. 58.97.
Va. II and III.
S. G. 8.5.
M. P. 1500°.

Occurrence. As smaltite, $CoAs_2$, and cobaltite, CoAsS.
Preparation. Reducing the oxide with hydrogen.
Properties. A white, magnetic, malleable metal. Its salts are pink. Used in Cobalt glass, which, when ground, gives the blue pigment, smalt.

Columbium, Cb.
At. wt. 93.5.
S. G. 12.7
M. P. 1950°.

A rare element. The metal is not affected by acids. It is weakly acidic and also weakly basic.

Copper, Cu.
At. wt. 63.57.
Va. I and II.
S. G. 8.9.
M. P. 1064°.

Occurrence. In oxide, carbonate and sulphide ores.
Preparation. The oxide is reduced with carbon. It is refined by electrolysis.
Properties. A red, lustrous, very ductile and malleable metal. The best electrical conductor next to silver. Dis-

CHEMICAL ELEMENTS — Continued

	solves readily in nitric acid, and in other acid when aided by oxygen. It is used for electrical conductors, for electroplating, as sheet copper, and in many alloys. The compounds are poisonous and are used in germicides, and insecticides. Blue vitriol is $CuSO_45H_2O$.
Dysprosium.	
Erbium.	
Europium.	
Fluorine, F.	Are rare earth elements, separated from other elements with great difficulty.
At. wt. 19.	**Occurrence.** Mostly in cryolite, Na_3AlF_6, and fluorite, CaF_2.
M. wt. 38.	**Preparation.** Electrolysis of hydrogen fluoride in a special cell.
Va. I.	**Properties.** A pale yellowish-green gas. The most violently active non-metallic element. Decomposes water, liberating oxygen as ozone. Hydrogen fluoride is used for etching glass and in the decomposition of silicates.
Gadolinium, Gd.	A rare earth element, difficult to separate.
Gallium, Ga.	A rare element found in some zinc blende. Like aluminum the oxide is both acidic and basic.
At. wt. 69.9.	
Germanium, Ge.	A rare element, having the properties intermediate between silicon and tin.
At. wt. 72.5.	
Glucinum (or Beryllium).	**Occurrence.** In beryl.
Gl. At. wt. 9.1.	**Preparation.** Electrolysis of the fused double fluoride.
Va. II.	**Properties.** A very light metal with the excellent qualities of aluminum to even a greater degree. But it is rare.
S. G. 1.8.	
Gold, Au.	**Occurrence.** Chiefly free, but also as telluride.
At. wt. 197.2.	**Preparation.** Gold bearing sands are washed, and the gold collected in mercury from which it is separated by distillation. When gold occurs in a very fine state it is dissolved from the powdered ore by cyanide.
Va. I and III.	
S. G. 19.32.	**Properties.** A very soft, brilliant, yellow metal, an excellent conductor, and the most ductile and malleable of all metals. It is very stable and insoluble in all acids, except aqua regia. It is both acidic and basic. Gold is alloyed with copper or silver to increase its hardness. The fineness of gold is expressed in carats, 24 carat gold is the pure metal.
M. P. 1062.4°.	
Helium, He.	**Occurrence.** In air about one part per million by volume. In large quantities in the atmosphere of the sun.
At. wt. 3.99.	**Preparation.** Fractional distillation of liquid argon. The lightest substance next to hydrogen. Combines with no other elements, and has the lowest B. P. of any substance.
M. wt. 3.99.	
B. P. 268.7°.	
Hydrogen, H.	**Occurrence.** 11.19% of all water, also in petroleum, natural gas, and all living organisms.
At. wt. 1.008.	**Preparation.** By electrolysis of water, and by the action of zinc and other metals upon several strong acids.
M. wt. 2.016.	
Va. I.	**Properties.** The lightest known substance. It is readily absorbed by a number of metals, especially by palladium. Combines powerfully with oxygen, fluorine and chlorine. In water, acids, living organisms and organic compounds it plays a most important role. It is used for filling balloons and in the oxy-hydrogen blowpipe.
B. P.—252.5°.	
Indium, In.	A rare element, occurring in zinc blende. Its vapor colors a flame blue.
At. wt. 114.8.	
Iodine, I.	**Occurrence.** In certain sea weeds, and in Chili saltpeter
At. wt. 126.92.	**Preparation.** Treating iodides with chlorine.
Va. I, V and VII.	**Properties.** Dark gray crystals with metallic luster. Its vapor is violet. Slightly soluble in water, but readily in alcohol, ether, carbon disulphide, chloroform and solutions of potassium iodide. Combines with many elements, but with less energy than chlorine and bromine. It colors starch blue. Used in medicine and in many organic syntheses.
S. G. 4.95.	
M. P. 114°.	
Iridium, Ir.	**Occurrence.** With platinum.
At. wt. 193.1.	**Properties.** A white and very hard metal. Not attacked by aqua regia or any acid. Used for hardening platinum.
S. G. 22.42.	
M. P. 1950°.	

CHEMICAL ELEMENTS — Continued

Iron, Fe.
At. wt. 55.85.
Va. II and III.
S. G. 7.86.
M. P. 1804°.

Occurrence. As the ores, magnetite, hematite, limonite, and siderite; also in pyrites and widely distributed through rocks and soils.
Preparation. In the blast furnace where the ores are reduced by carbon monoxide, and other matter is run into slag. The result is pig iron from which the different kinds of iron and steel are prepared. The essential difference in these is due to the varying proportions of carbon contained, and the influence of small amounts of other metals alloyed with steel. Mn., Ni., Cr., Mo., W., V., Ti., Si. and Cu., are all used to impart special properties to steel. The carbon content varies from 2% to 5% in cast iron; .2% to 1.5% in steel; and less than .2% in wrought iron.
Properties. A white, malleable, ductile and magnetic metal. It rusts in moist air, and dissolves readily in dilute acids. It is by far the most important metal in the extent and the varied applications of its usefulness. Some of its compounds are used in medicine, and green vitriol ($FeSO_47H_2O$) is used as a disinfectant, in dyeing and in the making of ink.

Krypton, Kr.
At. wt. 82.9.

Occurrence. In minute quantity in air.
Properties. Like argon, forms no chemical combinations.

Lanthanum, La.
At. wt. 139.0.
Va. III.

Occurrence. In the rare mineral lanthanite.
Properties. An iron gray metal, malleable and ductile. It is unstable, and reacts with water.

Lead, Pb.
At. wt. 207.1.
Va. II and IV.
S. G. 11.4.
M. P. 326°.

Occurrence. Principally as galena (PbS).
Preparation. Partial roasting of the ore, then continuing the heating in a closed furnace. The crude metal is then purified.
Properties. A soft, gray metal, malleable but of small ductility. It is stable in air, is but little affected by acids, excepting nitric acid. Heated in air it forms the oxide litharge (PbO) which oxidizes to red lead (Pb_3O_4) on further heating. It is used for water pipes, as sheet lead, lead foil, in shot, storage batteries, and in a number of important alloys. The basic carbonate, "white lead" is the most important basis of paints.

Lithium, Li.
At. wt. 6.94.
Va. I.
S. G. 0.53.

Occurrence. In some rare minerals, and in some mineral waters.
Preparation. By electrolysis of the fused chloride. A silver white, soft metal, that tarnishes quickly in air, decomposes water, and combines readily with nitrogen. The carbonate is used in medicine. Lithium salts color flames carmine red.

Magnesium, Mg.
At. wt. 24.32.
Va. II.
S. G. 1.75.
M. P. 633°.

Occurrence. Widely distributed in carbonates, as magnesite and dolomite, as sulphate, chloride, and in many silicate rocks.
Preparation. Electrolysis of fused carnallite.
Properties. A silver-white, tough metal, ductile when hot. It tarnishes in air, decomposes boiling water, is very active toward acids, and burns with an exceedingly dazzling bright light. The sulphate, "epsom salts," and the oxide and carbonate are used in medicine. Magnalium, the alloy with aluminum is light and strong and has important uses.

Manganese, Mn.
At. wt. 54.93.
Va. II, III, IV, VI and VII.
S. G. 8.0.

Occurrence. Principally pyrolusite (MnO_2), also as Mn_2O_3, and Mn_3O_4, and as a minor constituent in many rocks.
Preparation. Reducing Mn_3O_4 with aluminum filings.
Properties. A hard steel-gray metal. It rusts in moist air, and dissolves in dilute acids. Used in steel manufacture and in alloys. Potassium permanganate, $KMnO_4$, is an important oxidizing agent and disinfectant.

Mercury, Hg.
At. wt. 200.
Va. I and II.
S. G. 13.6.

Occurrence. Free and as cinnabar (HgS).
Preparation. By roasting cinnabar and distilling off the mercury. A silver-white liquid metal. It is stable in air and is dissolved by nitric acid, and aqua regia. Used in

CHEMICAL ELEMENTS — Continued

M. P.—39.5°.
B. P. 356.95°.

Molybdenum, Mo.
At. wt. 96.
Va. III, IV, V and VI.
S. G. 9.0. M. P. 2110°.

many scientific instruments and in the extraction of gold from its ores. It forms alloys called amalgams with many metals. Its salts are poisonous, some are used in medicine and the bichloride as a powerful germicide.

Occurrence. As molybdenite (MoS_2).

Preparation. By reducing the oxide with aluminum. A white malleable metal, insoluble in dilute acids. It is used in steels.

Neodymium, Nd.
At. wt. 144.3.

A rare element occurring with other rare earth elements.

Neon, Ne.
At. wt. 20.2.

Occurrence. Along with argon, which it resembles in properties.

Nickel, Ni.
At. wt. 58.68.
Va. II and III.
S. G. 8.9.
M. P. 1385°.

Occurrence. In combination with arsenic and sulphur.

Preparation. Reducing the oxalate in hydrogen.

Properties. A white, hard, lustrous metal, malleable, ductile and tenacious. It is stable in air, but dissolves readily in nitric acid. Its salts are green. It is used in plating and in a number of important alloys.

Nitrogen, N.
At. wt. 14.01.
M. wt. 28.
Va. III and IV.
B. P.—194°.

Occurrence. Four-fifths of the atmosphere, also in ammonia, nitrates, all living organisms, and in many organic compounds.

Preparation. Removing the other constituents of air, or by heating ammonium nitrite.

Properties. A colorless, odorless gas, inactive, but though it is brought into combination with difficulty, its compounds are exceedingly numerous and important. The most common of the compounds are ammonia (NH_3), and nitric acid (HNO_3).

Osmium, Os.
At. wt. 190.9.
S. G. 22.48.
M. P. 2400°.

Occurrence. Along with platinum.

Properties. The heaviest known metal. It has the highest known valence of VIII, and its principle compound is the tetroxide (OsO_4).

Oxygen, O.
At. wt. 16.
M. wt. 32.
Va. II.
B. P.—184°.

Occurrence. Free in the air of which it forms one-fifth. It constitutes eight-ninths of water, and nearly fifty per cent of the earth.

Preparation. By heating potassium chlorate, or barium dioxide.

Properties. A colorless gas, but it is blue in deep layers, slightly heavier than air. It is soluble in water to the extent of three volumes in 100 of water. It is exceedingly active, and combines with nearly all elements. Its oxides form the basis of most of inorganic chemistry. Its uses in respiration and combustion are fundamental to life and civilization.

Palladium, Pd.
At. wt. 106.7.
S. G. 11.9.
M. P. 1535°.

Occurrence. Along with platinum.

Properties. Resembles silver and platinum. Dissolves in nitric acid. The metal may absorb up to 900 times its volume of hydrogen.

Phosphorus, P.
At. wt. 31.04.
Va. III and V.

Occurrence. As phosphates in apatite and other minerals, in small quantities in all soils. It constitutes the chief mineral matter of bones, and is a necessary constituent of the tissues.

Preparation. Reducing calcium phosphate with carbon and sand in the electric furnace.

Properties. Phosphorus exists in two forms: the yellow form which is waxy, dissolves in carbon disulphide, melts at 44°, ignites at a very low temperature, and burns with great energy. It is very poisonous. Red phosphorus is a crystalline powder, insoluble in carbon disulphide, acts with less energy and is non-poisonous. Phosphorus is used for the heads of matches, and the phosphates are important as fertilizers.

Platinum, Pt.
At. wt. 195.2.
Va. II and IV.
S. G. 21.48.
M. P. 1753°.

Occurrence. Free, alloyed with the other platinum metals.

Preparation. The separation of the metals is complex.

Properties. A silvery metal, tenacious, ductile and malleable. Resists all acids, but dissolves slowly in aqua regia. Because of this resistance and its high melting point it is in-

CHEMICAL ELEMENTS — Continued

valuable for chemical vessels. It also is the only metal that can be successfully fused into glass, hence its use in electric lamps.

Potassium, K.
At. wt. 39.1.
Va. I.
. G. 86.
M. P. 62.5°.

Occurrence. As chloride, sulphate, nitrate, feldspar, and many other silicates. It is a necessary constituent of soils, and of plants and animals.
Preparation. Electrolysis of fused potassium hydroxide.
Properties. A very soft, silver-white metal. It tarnishes instantly in moist air, and is one of the most active of the metals. Caustic potash (KOH) is the strongest base of available metals, and forms salts with all acids. These salts have various applications.

Praseodymium, Pr.
At wt. 140.6.

One of the rare earth elements, occurring with cerium and lanthanum.

Radium, Ra.
At. wt. 226.4.
Va. II.

Occurrence. In minute quantities along with uranium.
Preparation. The residues from uranium ores, after extracting the uranium, are treated so as to separate the radium and barium as bromides. These are then separated by fractional crystallization.
Properties. Radium in any form emits three kinds of rays, different from light. These pass through objects opaque to light, and affect photographic plates and phosphorescent screens. It has been used successfully in the treatment of cancer.

Rhodium, Rh.
At. wt. 102.9.

Occurrence. In platinum ores, and is of the general character of the platinum metals.

Rubidium, Rb.
At. wt. 85.45.
Va. I.
S. G. 1.52.

Occurrence. In minute amounts along with potassium salts, and it strongly resembles potassium in all its properties.

Ruthenium, Ru.
At. wt. 101.7.

Occurrence. In ores of platinum. Of the general character of the platinum metals, resembling especially osmium, and like it forms several oxides.

Samarium, Sa.
At. wt. 150.4.

A rare metal, resembling in general the rare earth elements in its properties.

Scandium, Sc.
At. wt. 44.1.

A typical rare earth element.

Selenium, Se.
At. wt. 79.2.
Va. II, IV and VI.

Occurrence. With sulphur and sulphides.
Preparation. Reducing selenious acid with sulphur dioxide.
Properties. The element occurs in three forms: the red amorphous, the red crystalline, and the blue-gray metallic. The latter conducts electricity, and its conductivity is greatly increased by light. Therefore, it is used in cells for measuring light. Its chemical compounds resemble those of sulphur.

Silicon, Si.
At. wt. 28.3.
Va. IV.
M. P. 1200°.

Occurrence. Silicon dioxide (SiO_2) occurs in sand and different forms of quartz. Most of the earth's crust is composed of silicates.
Preparation. Reducing sand by heating with magnesium powder. Amorphous silicon is a brown powder, that burns in air. Crystalline silicon forms black needles and is less active. Silicon is used in steel making. Some quartz and silicates are used as gems. Quartz sand is used in manufacturing glass. Silicon carbide (SiC) "Carborundum" is nearly as hard as the diamond and is used as an abrasive.

Silver, Ag.
At. wt. 107.88.
Va. I.
S. G. 10.53.
M. P. 960°.

Occurrence. Native and as sulphide, usually accompanying galena.
Preparation. Separated from lead by the Pattison or the Parkes process. Separated from gold by nitric acid.
Properties. A white, lustrous, tough, very ductile and malleable metal, the best conductor of heat and electricity. It is not oxidized by air, but it is tarnished by hydrogen sulphide. It dissolves in dilute nitric and in boiling concentrated sulphuric acid. Uses, for coinage, and for many useful articles and ornaments. Silver nitrate is used as

CHEMICAL ELEMENTS — Continued

	"lunar caustic" in cauterizing and to make the silver halides used in photography. Potassium silver cyanide, $KAg(Cn_2)$, is used in plating.
Sodium, Na. At. wt. 23.0. Va. I. S. G. 0.97. M. P. 95.6°.	**Occurrence.** As salt (NaCl), nitrate, borate, carbonate, and in many silicates. **Preparation.** Electroylsis of the fused hydroxide or chloride. **Properties.** A silver-white metal, soft as wax. It is very active, readily decomposes water and resembles potassium generally. Sodium hydroxide is a powerful base which forms salts with all acids. Most of these salts have their application.
Strontium, Sr. At. wt. 87.63. Va. II. S. G. 2.55.	**Occurrence.** As carbonate and sulphate. **Preparation.** Electrolysis of the fused chloride. **Properties.** A light, active metal resembling calcium. It decomposes water vigorously. Its vapors color flames red, and it is therefore used for red fire in pyrotechny.
Sulphur, S. At. wt. 32.07. Va. II, IV and VI. M. P. 114.5°.	**Occurrence.** Free and combined with metals as sulphides and sulphates. **Preparation.** Melting the native sulphur and draining it off from the rocks and earth with which it is mixed. It is then purified by distillation. **Properties.** It exists in two crystalline and one amorphous form. The rhombic form is the stable variety into which the others change on standing below 96°C. This variety is a brittle light yellow solid, soluble in carbon disulphid. It burns in air to sulphur dioxide (SO_2) and it combines with most metals to form sulphides. Sulphur is used for vulcanizing rubber, in gunpowder, fireworks and matches. SO_2 is used for bleaching, disinfecting and in the manufacture of sulphuric acid. The latter is the most important of all chemicals.
Tantalum, Ta. At. wt. 181. S. G. 16.6. M. P.—2250°.	**Occurrence.** In rare minerals along with rare earth elements. **Preparation.** Reduction of the fluoride by sodium. **Properties.** A hard silver-white metal of great strength and stability. Used for filaments in electric lamps.
Tellurium, Te. At. wt. 127.5°. Va. II, IV and VI.	**Occurrence.** Free and as tellurides. **Preparation.** Reduction of tellurious acid by sulphur dioxide. **Properties.** Similar to those of sulphur and selenium, but is less acidic.
Terbium, Tb. At. wt. 159.2. Va. III.	**Occurrence.** In rare earth minerals, and it has the general properties of these elements.
Thallium, Tl. At. wt. 204. Va. I and II.	**Occurrence.** In flue dust of sulphuric acid works. A bluish metal resembling lead, and has a rather high chemical activity.
Thorium, Th. At. wt. 232. Va. IV.	**Occurrence.** In monozite sand. **Preparation.** By electrolysis. Welsbach mantles consist of 99% thorium dioxide.
Thulium, Tm. At. wt. 168.5.	A rare earth element, associated with others of the group.
Tin, Sn. At. wt. 119. Va. II and IV. S. G. 7.3. M. P. 232°.	**Occurrence.** As cassiterite (SnO_2). **Preparation.** Roasting the ore then reducing this by ignition with carbon. **Properties.** A silver-white metal, rather soft, very malleable ductile and stable in air. It is used for tin plating iron and copper, and in a number of alloys.
Titanium, Ti. At. wt. 48.1. Va. II, III and IV. M. P. 1850°.	**Occurrence.** As rutile (TiO_2) and titanic iron ore. **Preparation.** Reducing the chloride with sodium. **Properties.** A hard, brittle metal that can be forged at a low, red heat. It unites with oxygen and nitrogen when heated. It is used in steel manufacture.
Tungsten, W. At. wt. 184.	**Occurrence.** As wolframite ($FeWO_4$) and as scheelite ($CaWO_4$).

CHEMICAL ELEMENTS — Continued

Va. II, IV, V and VI. S. G. 19.3. M. P. 2800°.	**Preparation.** Reduction of the trioxide by carbon at high temperatures. **Properties.** A hard, gray metal, burns in air and combines with chlorine at 250°. It is used in tungsten steel, and for filaments in incandescent lamps.
Uranium, U. At. wt. 238.5. Va. III, IV, V, and VI. S. G. 18.7.	**Occurrence.** As pitchblende (U_3O_8). **Preparation.** Reducing the oxide with aluminum. **Properties.** A white radio active metal, tarnishes in air and is fairly active.
Vanadium, V. At. wt. 51.06. Va. II, III, IV and V.	**Occurrence.** Rather rare, in vandinite, and accompanying other metals. **Preparation.** Reducing VCl_2 in hydrogen. **Properties.** A silver-white metal, stable in air, burns in oxygen, and combines with nitrogen when heated. It is used in special high grade steel.
Xenon, Xe. At. wt. 130.2.	The heaviest gas of the argon group, with the general group properties.
Ytterbium, Yb. At. wt. 172.	In rare earth minerals. A rare earth element.
Yttrium, Y. At. wt. 89.	A rare earth element, associated in rare minerals with other related elements.
Zinc, Zn. At. wt. 65.37. Va. II. S. G. 6.9. M. P. 419°.	**Occurrence.** As zinc blende (ZnS) principally, but also as carbonate, oxide and silicate. **Preparation.** Roasting the ore and reducing this with carbon. The zinc is distilled off. **Properties.** A bluish-white metal, brittle but malleable at 120°. It is rather active. It is used as sheet zinc and for galvanizing iron, in galvanic batteries, and in alloys. The oxide (zinc white) is a valuable constituent of paint.
Zirconium, Zr. At. wt. 90.6. Va. IV.	**Occurrence.** As zircon ($ZrSiO_4$). **Preparation.** Reducing the oxide with carbon in the electric furnace. A hard, gray metal, stable in air.

Definitions: A Chemical Element is a simple kind of matter, which cannot be resolved into two or more other substances by any chemical means. There are about eighty elements which combine to form the many thousands of substances found in the world.

The **Atomic Weights** are the unit weights of the elements which enter into chemical combination. They are based upon the atomic nature of matter. The elements are conceived to be made up of exceedingly minute particles or atoms, which for any given element have a definite characteristic weight. The atomic weight of Oxygen is represented by the number 16, and the relative weights of the atoms of other elements are expressed in comparison with this number.

The **Symbol** for an element stands for the name of the element and also represents its atomic weight.

A **Formula** stands for a substance and represents by symbols the elements which form it, and the proportions in which they are contained. e. g. CO_2 represents carbon dioxide, and shows that one atomic weight of carbon of 12 weight units is combined with two atomic weights of oxygen or 2 x 16 weight units. In other words it shows that 44 grams of the gas contain 12 grams of carbon and 32 grams of oxygen.

Electrolysis is the process of decomposing substances by means of the electric current. Many compound substances called electrolytes when dissolved in water or when in a molten condition, will conduct the electric current. But unlike a wire which suffers no chemical change from the passage of a current, electrolytes are decomposed by a current—the metallic part collecting on the negative pole and the non metallic part at the positive pole of the battery.

Note: In addition to the chemical elements described in the foregoing table, brief mention should be made of six others. **Holmium, Ho,** was first isolated by Soret in 1879; **Lutecium, Lu,** by Welsbach in 1906. **Niton, Nt,** isolated by Rutherford, is continually generated by the element radium. **Illinium, Il,** one of the rare earth series, was discovered by Hopkins in 1926 at the University of Illinois. **Virginium, Vi,** and **Alabamine, Ab,** discovered by Allison and associates at the Alabama Polytechnic Institute, completed the entire list of elements.

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